USAAEFA PROJECT NO. 82-14

PRELIMINARY AIRWORTHINESS EVALUATION OF THE UH-60A CONFIGURED WITH THE EXTERNAL STORES SUPPORT SYSTEM (ESSS)
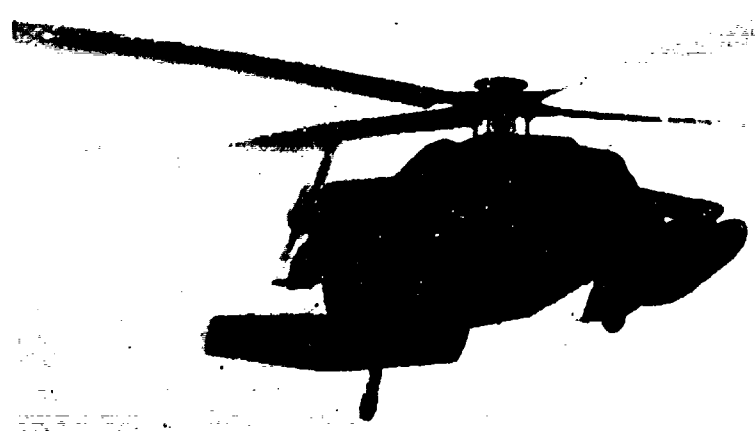
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MARCH 1983

FINAL REPORT

UNITED STATES ARMY AVIATION ENGINEERING FLIGHT ACTIVITY
EDWARDS AIR FORCE BASE, CALIFORNIA 93523

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The Preliminary Airworthiness Evaluation of the UH-60A helicopter (USA S/N 77-22714) configured with the External Stores Support System was conducted at the Sikorsky Flight Test Facility, West Palm Beach, Florida (elevation 28 feet). A total of 26 test flights were conducted, between 4 December 1982 and 26 January 1983 and 20.2 productive hours were flown. Limited level flight performance tests were conducted to determine the change in

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drag of the UH-60A helicopter caused by three External Stores Support System configurations with various stores installed. An unexplained increase in power required was found between the Preliminary Airworthiness Evaluation test aircraft and the aircraft used during a previous Airworthiness and Flight Characteristics evaluation. The maximum range for the self deployment ferry mission was determined by US Army Aviation Research and Development Command using the power required obtained from this report to be 1176 nautical miles in the original External Stores Support System with four tanks configuration. This exceeded the 1150 nautical mile requirement for the self deployment ferry mission described in the Material Need Document.

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DEPARTMENT OF THE ARMY
HQ, US ARMY AVIATION RESEARCH AND DEVELOPMENT COMMAND
4300 GOODFELLOW BOULEVARD, ST. LOUIS, MO 63120

DRDAV-D

SUBJECT: Directorate for Development and Qualification Position on the Final
Report of USAAEFA Project No. 82-14, Preliminary Airworthiness
Evaluation of the UH-60A Configured with the External Stores Support
System (ESSS)

SEE DISTRIBUTION

1. The purpose of this letter is to establish the Directorate for Development
and Qualification position on the subject report. In addition to documenting
the test results of the subject evaluation, this report also identifies a
significantly higher and unexplained increase in power required for the test
aircraft as compared to the results of the Airworthiness and Flight Character-
istics (A&FC) evaluation, USAAEFA Project No. 77-17.

2. The self deployment range for the UH-60A equipped with the ESSS, 4 fuel
tank configuration has been calculated by this Directorate. The calculations
are based on the test data of this report (used to increment the A&FC baseline)
and show that the UH-60A range is 1176 nautical miles with the standard ESSS
4 tank configuration and 1207 nautical miles with the ESSS 4 tank configuration
with the modified vertical pylon fairings. The unexplained power required
increase found for the subject test aircraft over the power required measured
for the aircraft used during the A&FC test has not been used to increment the
baseline during the range calculations. The ground rules for the range calcula-
tions are 10 knots headwind and 10% mission fuel reserve as quoted in the BLACK
HAWK Material Need Document (Reference 1 in report). Based on the fact that
the calculations indicate the South Atlantic route can be flown with the standard
ESSS, this Directorate has recommended to the Project Manager that the modified
fairings for the vertical pylons not be procured.

3. This Directorate agrees with the conclusions stated in this report. There
were no reported shortcomings or deficiencies associated with this evaluation.
An evaluation has been tentatively planned for performance testing of a UH-60A,
with production ESSS fixed provisions, to be done at USAAEFA.

FOR THE COMMANDER:

2 Encl   CHARLES C. CRAWFORD, JR.
as   Director of Development
                                          and Qualification

TABLE OF CONTENTS

INTRODUCTION

BACKGROUND

1. The United States Army has stated a requirement for a self deployment capability for the UH-60A helicopter. Sikorsky Aircraft (SA) Division of United Technologies has designed the External Stores Support System (ESSS) to satisfy this requirement. Specific self deployment mission requirements are contained in the Material Need Document (ref 1, app A).

2. In November 1982 the United States Army Aviation Engineering Flight Activity was tasked by the United States Aviation Research and Development Command (AVRADCOM) (ref 2, app A) to plan, conduct, and report on the Preliminary Airworthiness Evaluation (PAE) of the UH-60A configured with the ESSS.

TEST OBJECTIVE

3. The objective of the PAE was to obtain limited level flight performance data for use by the AVRADCOM Directorate for Development and Qualification to determine if the UH-60A with the ESSS installed meets the self deployment capability requirement.

DESCRIPTION

4. The test helicopter, UH-60A Black Hawk US Army S/N 77-22714, was configured with the ESSS (photo 1). The ESSS for the Black Hawk consists of the airframe fixed provisions and the external stores subsystem. The external stores subsystem is comprised of a horizontal stores support, two support struts, and two vertical stores pylons for each side of the aircraft. The pylons are designed to accommodate 450 gallon fuel tanks at the inboard stations and 230 gallon fuel tanks at the outboard stations. All stores stations are designed to permit jettison of loads. A fuel transfer system was not installed in the test aircraft. A description of the standard UH-60A Black Hawk can be found in the operator's manual (ref 3, app A) and a more detailed description of the ESSS is included in appendix B.

TEST SCOPE

5. The PAE was conducted at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet) and consisted of level flight performance testing. A total of 26 flights were conducted between 4 December 1982 and 26 January 1983 for a total of 20.2 productive flight hours. SA calibrated and maintained

1

Photo 1. UH-60A in the Modified ESSS with Four Tanks Configuration

2

all test instrumentation and performed all required maintenance on the test helicopter. Flight restrictions and operating limitations observed during the PAE are contained in the operator's manual (ref 3, app A) and the airworthiness release (ref 4, app A). Testing was conducted in accordance with the test plan (ref 5, app A) at the conditions shown in table 1. These conditions were based on the requirements of the Material Need Document (ref 1, app A).

TEST METHODOLOGY

6. Flight test data were obtained from test instrumentation displayed on the instrument panel and recorded on magnetic tape installed in the aircraft. A detailed list of test instrumentation is contained in appendix C. Established flight test techniques and data analysis procedures used are described in appendix D.

Table 1. Level Flight Performance Test Conditions[1]

Configuration	Gross Weight Range (lb)	Average Longitudinal Center of Gravity (FS)	Density Altitude Range (ft)	Calibrated Airspeed Range (KT)	Thrust Coefficient Range (x10⁴)
Fixed Provisions[2]	16,040 to 18,000	347.0	6580 to 7680	30 to 147	70.20 to 80.14
Original ESSS with No Stores[3]	16,080 and 17,960	347.0	6740 and 7300	38 to 137	70.20 and 80.32
Original ESSS with Two Tanks[3]	17,900 to 21,880	347.0	7660 to 5120	36 to 140	70.14 to 90.18
Original ESSS with Four Tanks[3]	17,960 and 24,560	343.0	1380 and 10,740	31 to 121	90.15 and 90.61
	16,000 to 17,960	350.0	6540 to 10,740	29 to 131	69.92 to 90.18
Modified ESSS with Four Tanks[4]	24,540	343.3	820	38 to 122	90.33
	16,080 to 24,460	350.0	5920 to 9640	41 to 136	70.07 to 100.16

NOTES:

[1]Test conducted in ball centered flight, all windows closed, a mid lateral center of gravity, and at a referred rotor speed of 258 RPM.
[2]Fixed provisions - normal utility configuration with ESSS mounting provisions enclosed by fairings.
[3]Original ESSS - normal utility configuration with the horizontal and vertical stores support system and ejector assemblies with the various stores installed.
[4]Modified ESSS - same as original ESSS but with extended pylon fairings added.

4

RESULTS AND DISCUSSION

GENERAL

7. Limited level flight performance and flight control position data were obtained for the UH-60A Black Hawk helicopter in three configurations (fixed provisions, original ESSS and modified ESSS) with various external stores installed. The flight tests were conducted at the Sikorsky Aircraft Division of United Technologies Flight Test Center in West Palm Beach Florida. Test site elevation was 28 feet. The aircraft was flown in ball-centered flight at a referred rotor speed of 258 RPM. The maximum range in the self deployment ferry mission configuration (original ESSS with four tanks) was calculated by AVRADCOM using the power required data contained in this evaluation. This range was determined to be 1176 nautical miles using a cruise climb flight profile and the criteria in the Material Need Document (ref 1, app A).

LEVEL FLIGHT PERFORMANCE

General

8. Initially, level flight performance tests were conducted in the fixed provisions configuration to provide a baseline to compare with the Airworthiness and Flight Characteristics (A&FC) Evaluation test results. Additional tests were conducted to determine the change in drag of the UH-60 helicopter configured with the original ESSS and with various stores installed. A modified ESSS with four tanks was also tested. These tests were conducted at the conditions of table 1. The data obtained were concentrated at thrust coefficients (C_T's) of approximately 0.007, 0.008, and 0.009. Test techniques and data analysis methods are described in appendix D. Installed engine power and fuel flow for the Black Hawk were derived by AVRADCOM from General Electric (GE) engine deck number 80024, dated 26 February 1981 using installed losses determined by AVRADCOM. All power required data were corrected by an estimate for drag of external test instrumentation and nonstandard aircraft equipment and for instrumentation electrical power consumption. All estimates for drag of these external items were provided by SA. The test results from the A&FC Evaluation of the UH-60A in the normal utility configuration (ref 6, app A) were normalized to the PAE test aircraft. These results were used as the basis for evaluating the effects of drag for the various configurations tested since the A&FC Final Report constitutes the broadest range of available performance data verified by flight test. An unexplained increase in power required was found between the PAE test aircraft and the aircraft used for the A&FC. A maximum range of 1176 nautical miles was determined by AVRADCOM, using the data from

5

this report, the latest self deployment ferry mission configuration, the criteria of the Material Need Document (ref 1, app A), and power required for a cruise climb and level flight cruise at the maximum range cruise airspeeds. This exceeds the 1150 nautical mile range required for the self deployment ferry mission.

Fixed Provisions Configuration

9. The fixed provisions configuration consisted of the Black Hawk in the normal utility configuration with the addition of the fixed ESSS mounting provisions enclosed by the fixed provisions fairings (fig. 1, and photos 2 and 3, app B). Level flight performance data was obtained on four flights, two of which (C_T = 0.007286 and 0.008014) were conducted with the Black Hawk standard stabilator schedule but with the ship system pilot's airspeed input to the stabilator amplifier replaced by the boom (test) system airspeed. These flights were repeated and all subsequent tests conducted with a modified stabilator schedule (fig. 2, app B) and an increased electrical time delay in the stabilator amplifier incorporated. In addition, the airspeed inputs to the stabilator amplifiers were returned to the standard Black Hawk configuration and the ship system airspeed probes rotated inboard 15 degrees about an axis normal to their mounting pad. The power required for level flight was the same for both stabilator schedules.

10. The power required for the fixed provisions configuration was expected to be equal to the A&FC test results with the addition of the fixed provisions drag estimate of 0.78 ft^2 change in equivalent flat plate area (ΔF_e). Initially, a significant amount of additional drag was found, approximately 7.5 ft^2 ΔF_e at high speeds. This amount was considered too large for this small configuration change and led to additional flight tests to verify the boom airspeed system position error provided by SA. The calibration was found to be incorrect and the error accounted for about 3 ft^2 of the drag increase. Other corrections described in paragraph 6, appendix D were applied to the A&FC data used as the baseline for this comparison and resulted in further reducing the difference to approximately 3 ft^2 at an advance ratio of 0.28 (approximately 120 knots true airspeed (KTAS)). The ΔF_e determined for the fixed provisions configuration varied with airspeed. A summary of ΔF_e at this advance ratio of all the configurations tested is presented in figure 1, appendix E. The fairing presented in figure 2, appendix E was derived from all the fixed provisions data, figures 3 through 6, and includes the still unexplained increase in power required between the PAE test aircraft and that of the A&FC aircraft in the same configuration. A performance

6

evaluation should be conducted on a late production UH-60A helicopter to determine if this power required increase is unique to the PAE test aircraft.

Original ESSS with Four Tanks Configuration

11. The original ESSS with four tanks configuration consists of the horizontal and vertical stores support systems (wing and pylons) and ejector rack assemblies with two 450 gallon fuel tanks mounted on the inboard store positions and two 230 gallon fuel tanks mounted on the outboard store positions (fig. 1, and photos 6 and 7, app B). Five flights were conducted in this configuration. Three were flown to determine C_T effects at a longitudinal center of gravity (CG) of fuselage station (FS) 350. The other two were flown at the forward CG limit, FS 343. This was to provide data over the range of C_Ts expected for the ferry mission as well as longitudinal CG effects. The flights at the limit forward CG were conducted near the same C_T but at different test conditions that were representative of the actual ferry mission.

12. Figure 7, appendix E presents a summary of the change in drag from the normal utility to the original ESSS with four tanks configuration. The ΔF_e varied with airspeed and C_T. Figures 8, 9, and 10 present the nondimensional data derived from the dimensional test data presented in figures 11 through 15. The drag increase for the ESSS with four tanks configuration was found to be higher than the amount predicted by SA, especially at the high C_T (approximately 0.0090), where much of the ferry mission flight profile is flown.

13. Test data was obtained to determine the effect on power required of changing the aircraft CG from FS 350.0 to the forward limit CG FS 343.0. The data used to evaluate these effects were obtained on two flights: one at a heavy gross weight (24,580 lb) and a low density altitude (1380 ft); and the other at a lighter gross weight (17,960 lb) and a higher altitude (10,740 ft). The results of these limited tests were inconclusive (figs. 14 and 15, app E). Sufficient testing should be accomplished in the ESSS configuration to define the change in power required by changes in aircraft CG.

Modified ESSS with Four Tanks Configuration

14. Si e the aircraft in the original ESSS with four tanks config ition was not expected to meet the required ferry mission range, modification to reduce the drag of the ESSS was incorporate by SA. The modified ESSS with four tanks configuration

7

was the same as the original ESSS configuration described in paragraph 11 except for fairings added to the vertical stores support system (pylons) to cover the ejector racks and extend from the original fairing to the top of the fuel tanks (photos 8 and 9, app B). Four flights at C_Ts near those obtained for the original ESSS data were conducted to determine if the drag was reduced and to evaluate the overall drag change form the normal utility configuration. Figure 16, appendix E presents a summary of the change in drag from the normal utility to the modified ESSS configuration. Figures 17 through 19 present the nondimensional data derived from the dimensional test data presented in figures 20 through 23. The ΔF_e was again found to vary with airspeed and C_T, similar to the data for the original ESSS configuration. The drag was substantially reduced at the low C_Ts but only slightly reduced (approximately 0.7 ft^2 ΔF_e) at $C_T = 0.009$ and 120 KTAS. A comparison at this air speed of the original and modified ESSS ΔF_e data over the range of C_Ts tested is presented in figure 1, appendix E.

Original ESSS with no Stores and with Two Tank Configurations

15. Data were also obtained for the original ESSS with no stores (horizontal and vertical stores support systems with no stores) (photo 4, app B) and the original ESSS with two 230 gallon fuel tanks installed at the outboard store positions (photo 5, app B). Figure 24, appendix E presents a summary of ΔF_e from the normal utility configuration for these two configurations. The non-dimensional data for the two tank configurations are presented in figures 25, 26 and 27 and the dimensional data for both configurations are presented in figures 28 through 32. The ΔF_e determined for both of these configurations were found to vary with airspeed and not with C_T as with the four tank data (fig. 1, app E). The ΔF_e for the original ESSS with no stores and with two tanks at approximately 120 KTAS was 11.8 ft^2 and 14.2 ft^2, respectively.

Self-Deployment Ferry Mission Range Estimate

16. The self deployment ferry mission ranges were calculated by AVRADCOM for the original and modified ESSS with four tanks configurations. These ranges were based on the requirements of the Material Need Document (ref 1, app A) and the data from the A&FC final report plus the ΔF_e determined for each configuration. Estimates for the drag of a "hover infrared suppressor" and main rotor deice equipment were also included. These items were not installed on the PAE test aircraft. Five nautical miles were added to the range estimate for the descent from 10,000 ft at the end of the mission. The unexplained increase in the power

8

required between the PAE and A&FC test aircraft was ignored for this calculation. The maximum range for the original ESSS with four tanks using these criteria was 1176 nautical miles. This exceeds the 1150 nautical mile range required for the self deployment ferry mission. The maximum range for the modified ESSS with four tanks was determined to be 1207 nautical miles for these same criteria.

INHERENT SIDESLIP

17. The inherent sideslip angles were measured during all test flights. No consistent difference was found between configurations but the inherent sideslip did vary with C_T. The data from all the test flights were grouped according to C_T and plots for inherent sideslip, (figures 33 and 34) were developed. The inherent sideslip characteristics for the PAE test aircraft were 1 to 3 degrees closer to zero sideslip than the A&FC test aircraft at high speeds. This unexplained difference was taken into account when normalizing the A&FC data for use in is report (para 7, app D).

HANDLING QUALITIES

Control Positions in Level Flight

18. Control positions in ball centered level flight were obtained in conjunction with the level flight performance data. The data from selected flights at each aircraft configuration tested are presented in figures 35 through 39. The trends of control positions with airspeed were similar to those of the standard UH-60A.

9

CONCLUSIONS

19. Based on the PAE of the UH-60A helicopter in the configurations tested, the following conclusions were reached:

a. Based on an AVRADCOM analysis using the power required data obtained from this report, the UH-60A in the original ESSS with four tanks configuration exceeds the 1150 nautical mile range required for the self deployment ferry mission (para 15).

b. There is an unexplained increase in the power required for level flight between the PAE test aircraft and the test results from the A&FC Evaluation of the UH-60A heliocpter (para 10).

c. The modification to the ESSS reduced the drag of the UH-60A in the ESSS configuration, especially at thrust coefficients less than 0.009 (para 14).

d. The inherent sideslip of the PAE test aircraft was 1 to 3 degrees less left sideslip than the test aircraft used during the A&FC (para 17).

RECOMMENDATIONS

20. Sufficient testing should be accomplished in the ESSS with four tank configuration to determine the change in power required by changes in aircraft CG (para 13).

21. A performance evaluation should be conducted on a late production UH-60A helicopter (para 10).

APPENDIX A. REFERENCES

1. Document, TRADOC, ATCD-B, UH-60A Blackhawk Material Need, Production, updated (MN)(P) (U), Action Control Number 10705, August 1979, with change dated 13 December 1980.

2. Letter, AVRADCOM, DRDAV-D, 5 November 82, subject: Preliminary Airworthiness Evaluation of the UH-60A Configured with the External Stores Support System (ESSS), with revision 1 dated 23 November 82. (Test Request)

3. Technical Manual, TM55-1520-237-10, *Operator's Manual, UH-60A Helicopter, Headquarters Department of the Army*, 21 May 1979, with change 19, dated 3 February 1983.

4. Letter, AVRADCOM, DRADAV-D, 12 January 1983, subject: Airworthiness Release for the Conduct of a Preliminary Airworthiness Evaluation of a UH-60A Configured with the External Stores Support System (ESSS), Project No. 82-14, with revision 2 dated 12 January 1983.

5. Test Plan, USAAEFA Project No. 82-14, *Preliminary Airworthiness Evaluation of the UH-60A Configured with the External Stores Support System*, 26 November 82.

6. Final Report, USAAEFA Project No. 77-17, *Airworthiness and Flight Characteristics Evaluation; UH-60A (Black Hawk) Helicopter*, September 1981, unpublished.

APPENDIX B. DESCRIPTION

1. The UH-60A is a twin engine, single main rotor configured helicopter with nonretractable wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20 degrees upward from the horizontal. Primary mission gross weight is 16,260 pounds and maximum alternate gross weight is 20,250 pounds. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines having an installed thermodynamic rating (30 minute) of 1553 SHP (power turbine speed of 20,900 RPM) each at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 SHP. The aircraft also has an automatic flight control and a command instrument system. The test helicopter, UH-60A US Army S/N 77-22714 was manufactured by SA, and is the first production Black Hawk. The main differences between the test aircraft and a standard UH-60A consist of special test instrumentation (app C), modified door jettison system (photo 1), nonstandard gunners windows (photo 2), and airframe fixed provisions for the ESSS. A fuel transfer system was not installed in the test aircraft.

2. The ESSS consists of the airframe fixed provisions and the removable external stores subsystem. The ESSS was designed to enable the UH-60A to carry external stores such as auxiliary fuel tanks or various weapons systems.

3. The airframe fixed provisions (fig. 1, and photos 2 and 3) are the fuselage attachment structure required for the installation of the removable external stores subsystem. The removable external stores subsystem (fig. 1 and photo 4) consists of the horizontal store support which is a composite boxed I-beam structure, the support struts (two on each wing) and the vertical stores pylons (two on each wing) all of which are enclosed with thin aluminum fairings. Ejector racks were mounted on the vertical stores pylons at a 4° nose up angle with reference to the aircraft water line. Model MAU-40 ejector racks were installed at the inboard and outboard stores stations.

4. The test aircraft was configured with various portions of the external range fuel system, which included two 230 gallon external fuel tanks on the outboard pylons (photo 5) and a combination of the two 230 gallon tanks with two 450 gallon fuel tanks on the inboard pylons (photos 6 and 7). Aluminum fairings were added between the vertical stores pylon fairings and the auxiliary tanks (photos 8 and 9) for certain flights.
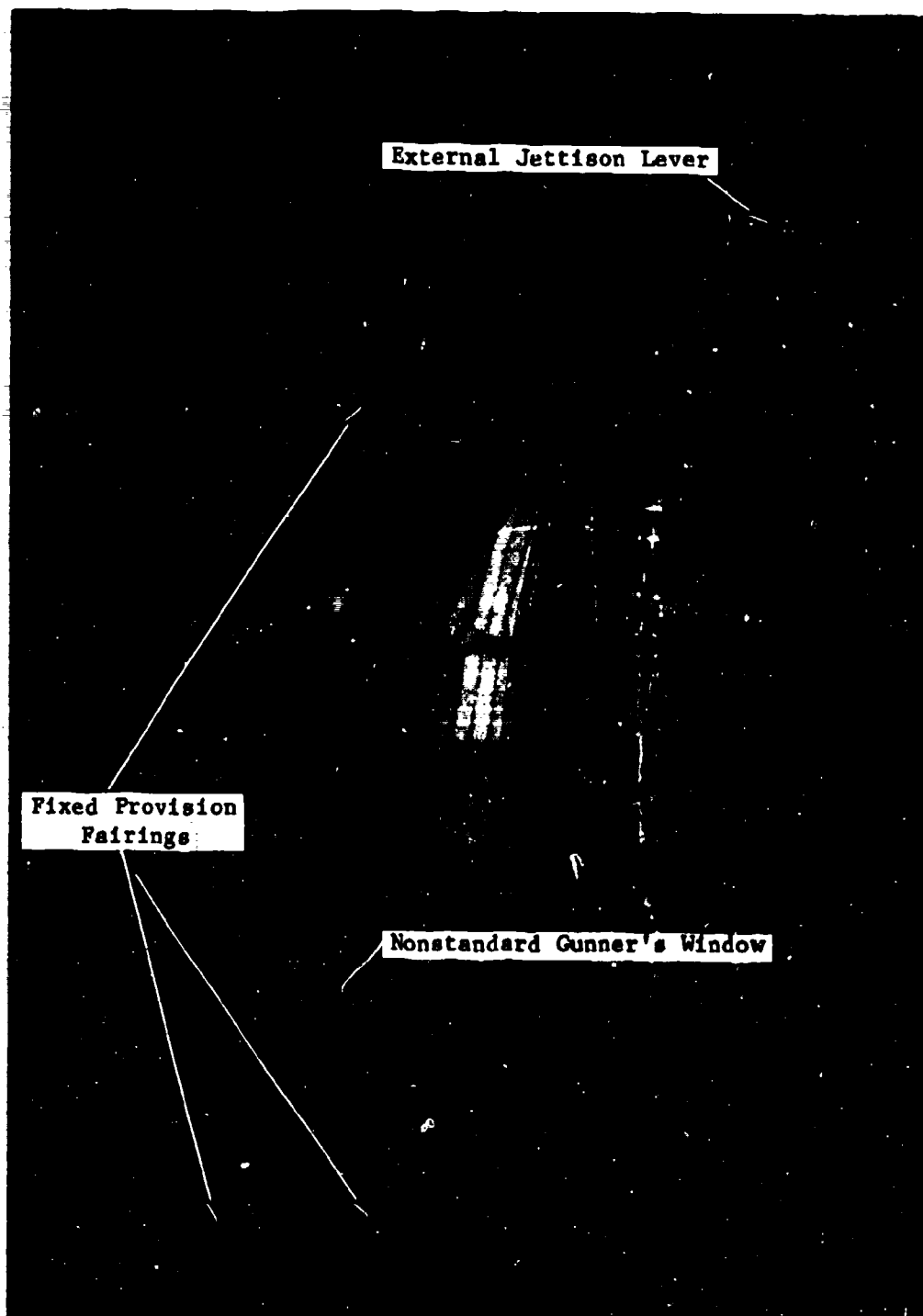
13

External Door Jettison Lever

Additional Door Handle

Photo 1. Modified Door Jettison System

14

Photo 2. UH-60A ESSS Fixed Provisions Configuration
(Fairings Installed)

15

HORIZONTAL STORE SUPPORT
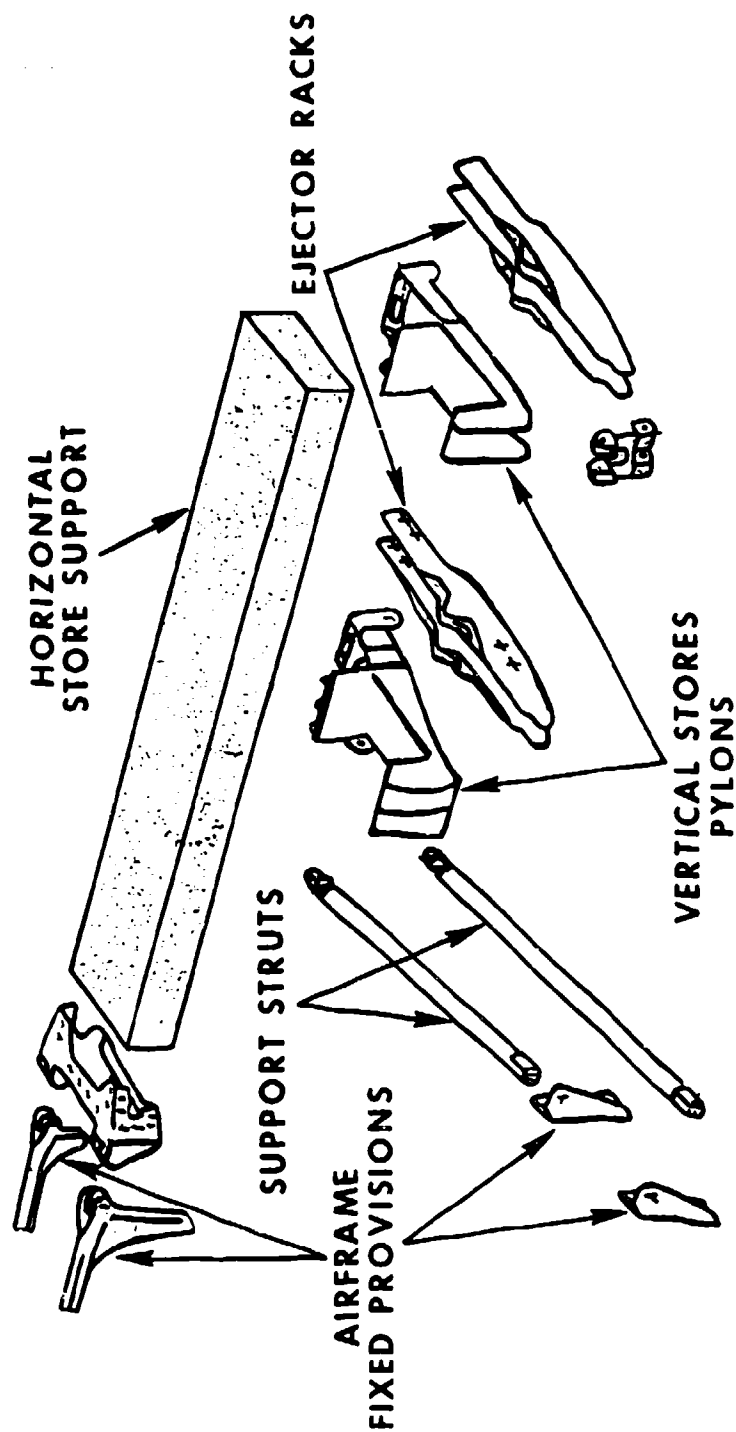
EJECTOR RACKS

VERTICAL STORES PYLONS

SUPPORT STRUTS

AIRFRAME FIXED PROVISIONS

Figure 1. ESSS Structural Components

16
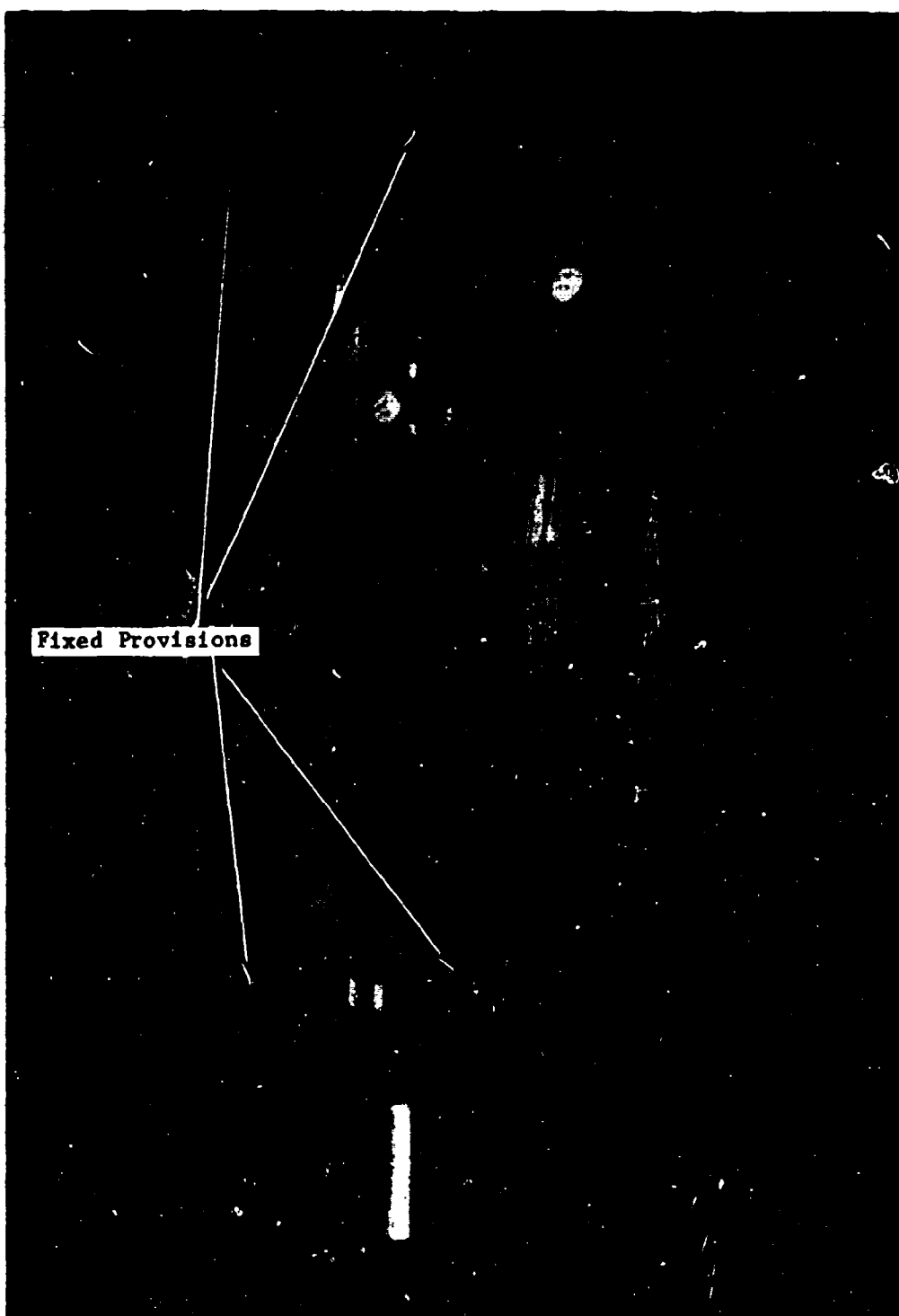
Photo 3. UH-60A ESSS Fixed Provisions Configuration
(Fairings Removed)

17

Horizontal Stores Support

Vertical Stores Pylon with Ejector Racks

Support Struts

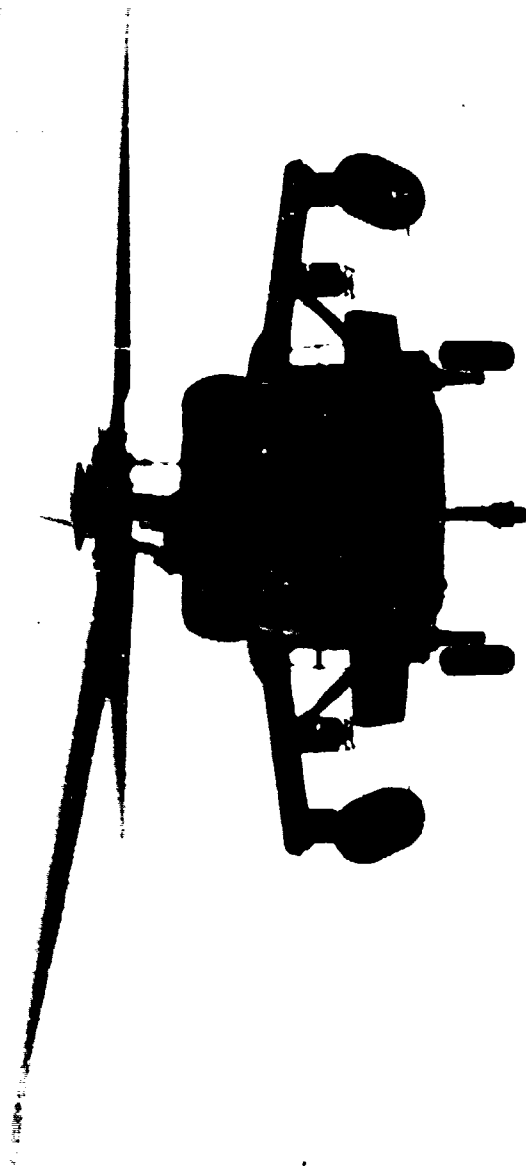Photo 4. UH-60A in the Original ESSS with No Stores Configuration

18

Photo 5. UH-60A in the Original ESSS with Two Tanks Configuration

19

Photo 6. UH-60A in the Original ESSS with Four Tanks Configuration

20

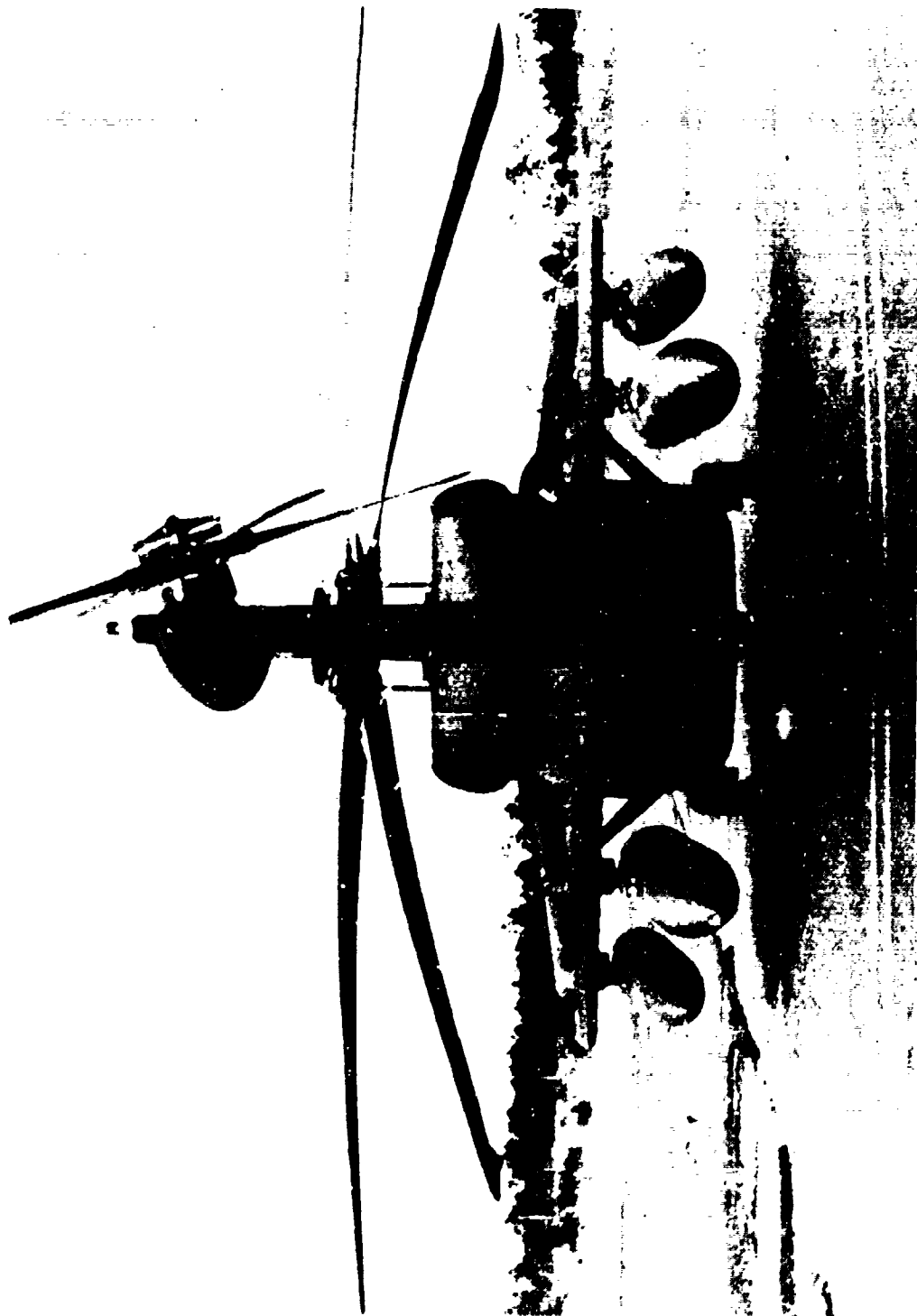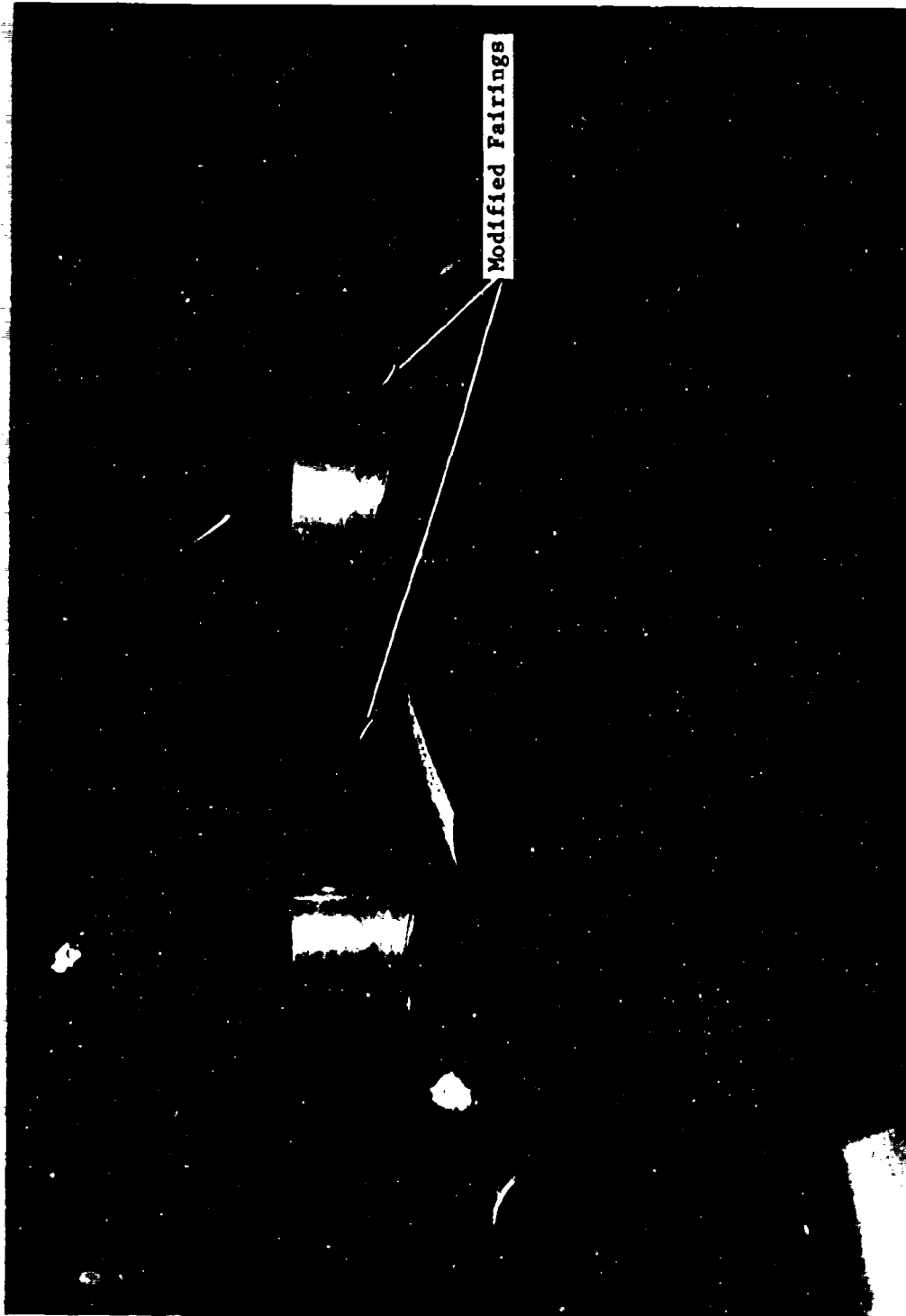Photo 7. UH-60A in the Original ESSS with Four Tanks Configuration - Rear View

21

Modified Fairings

Photo 8. UH-60A in the Modified ESSS with Four Tanks Configuration
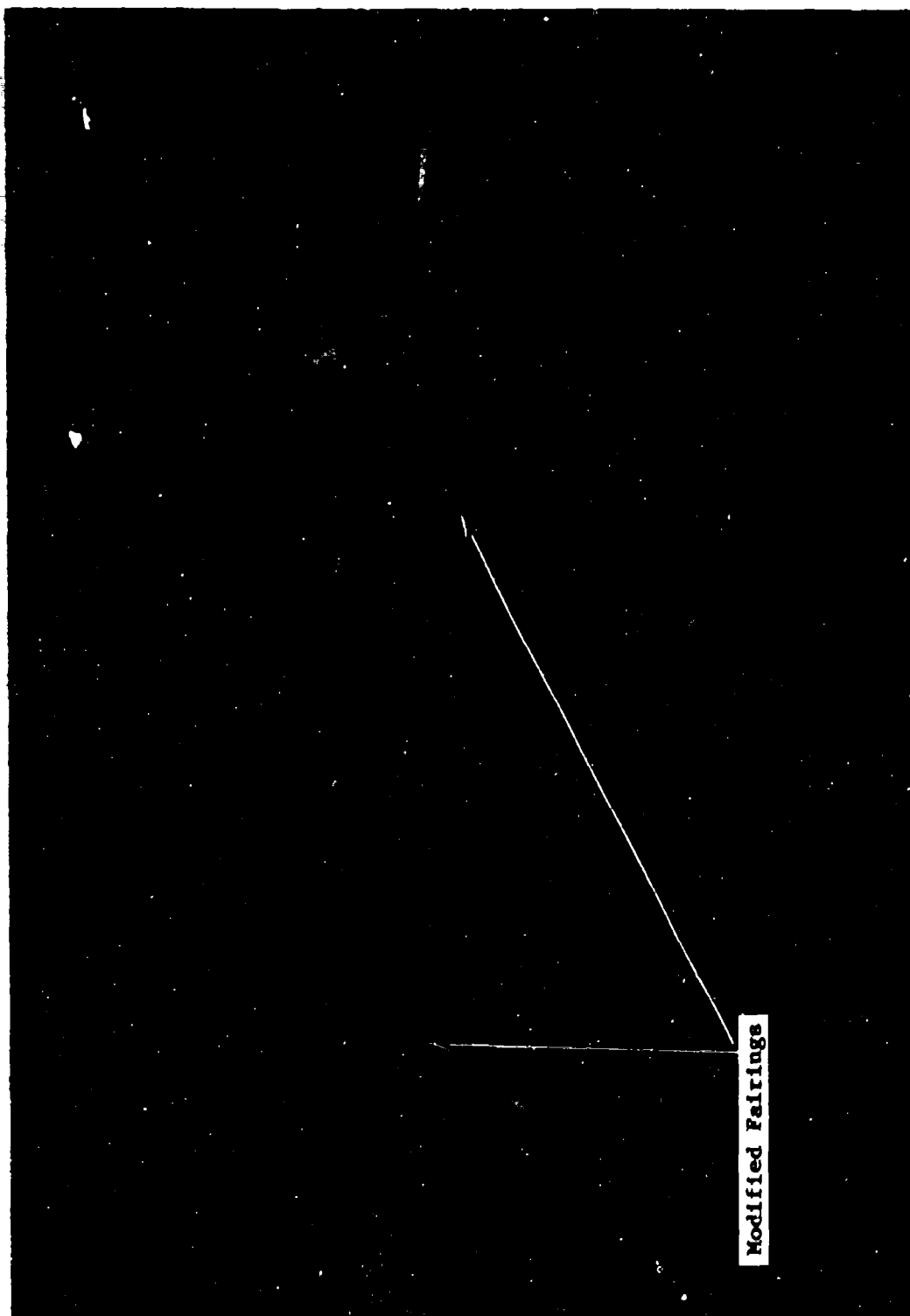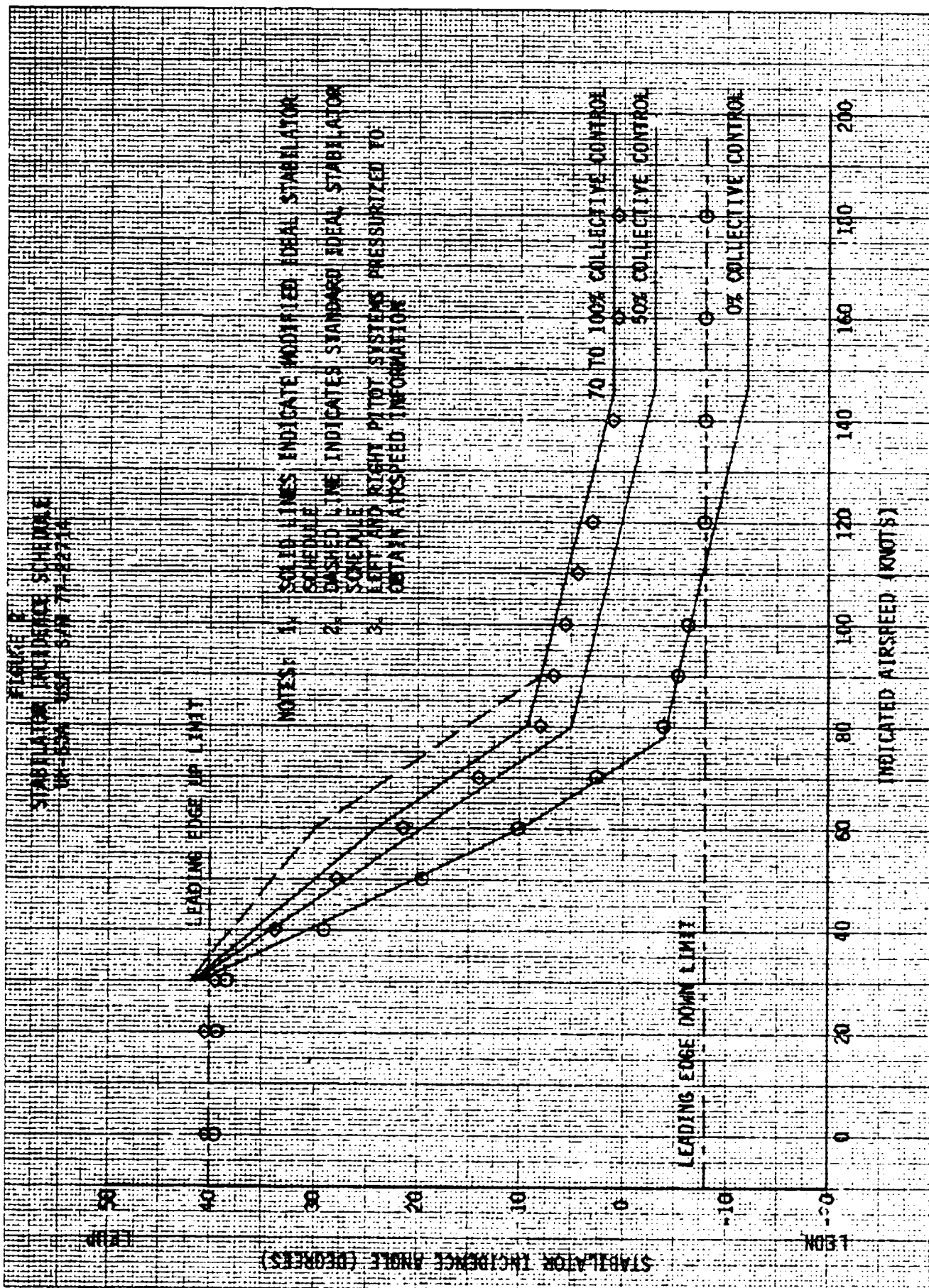
Modified Fairings

Photo 9. UH-60A in the Modified BSSS with Four Tanks Configuration - Rear View

5. The first two flights of the PAE were flown with the standard Black Hawk stabilator schedule and ship system airspeed probe orientation but with the ship system pilot's input to the stabilator replaced by the boom system airspeed. Theses flights were conducted in the fixed provisions configuration. After these two flights were completed, the gain control module of the stabilator amplifiers were modified to increase the electrical time delay to 3 seconds and change the stabilator schedule (stabilator incidence angle bias with collective control position) in the test aircraft. The modified stabilator schedule is presented in figure 2. The airspeed inputs to the stabilator were returned to the standard Black Hawk configuration; the copilot's ship system airspeed providing the input to the No. 1 stabilator amplifier and the pilot's ship system airspeed providing the input to the No. 2 stabilator amplifier. Along with the stabilator control modifications, the orientation of both ship system airspeed probes was changed by rotating both probes inboard 15 degrees about an axis normal to their mounting pad.

6. Several external modifications were made to the test aircraft for instrumentation or safety. These modifications were not part of the ESSS modifications or a standard UH-60A. Drag estimates for these items totalled 3.68 ft^2 of equivalent flat plate area. Each item is listed below:

ITEM

Tail rotor slip ring assembly
Main rotor slip ring assembly
Airspeed boom
Instrumented main rotor blade (1)
Ambient air temperature sensor
Telemetry antenna
Tail rotor junction plate
External instrumentation wiring
Emergency crew door handles
Non-standard gunner's window

24

STABILATOR INCIDENCE SCHEDULE FIGURE
STABILATOR INCIDENCE SCHEDULE
UH-60A USA S/N 77-22714

NOTES: 1. SOLID LINES INDICATE MODIFIED IDEAL STABILATOR SCHEDULE
2. DASHED LINE INDICATES STANDARD IDEAL STABILATOR SCHEDULE
3. LEFT AND RIGHT PITOT SYSTEMS PRESSURIZED TO OBTAIN AIRSPEED INFORMATION

LEADING EDGE UP LIMIT
LEADING EDGE DOWN LIMIT

70 TO 100% COLLECTIVE CONTROL
50% COLLECTIVE CONTROL
0% COLLECTIVE CONTROL

STABILATOR INCIDENCE ANGLE (DEGREES)

INDICATED AIRSPEED (KNOTS)

25

APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by the SA personnel. A specially constructed boom, with a swiveling pitot-static tube and angle of attack and sideslip vanes, was installed at the nose of the aircraft. The boom design (photo 1) allowed takeoffs and ground handling ease at heavy gross weights without damaging the pitot-static tube. Figure 1 presents the position error correction for the boom airspeed system. Major external instrumentation items such as the airspeed boom and main and tail rotor slipring assemblies are shown in photo 1. Data was obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

Airspeed (boom)
Altitude (ship's)
Altitude (radar)
Rate of climb*
Rotor speed (sensitive)
Engine torque * **
Turbine gas temperature * **
Power turbine speed (N_p)* **
Gas producer speed (N_g)* **
Control positions
    Longitudinal
    Lateral
    Directional
    Collective
Horizontal stabilator position
Turn and slip indicator*

Copilot Panel

Event switch
Airspeed*
Altitude*
Rotor speed*
Engine torque* **

Engineer Panel

Fuel remaining
Instrumentation controls

*Ship's system/not calibrated
**Both engines

26

Free air temperature
Time code display
Run number
Event switch

2. Data parameters recorded on board the aircraft include the following:

<u>Digital (PCM) Data Parameters</u>

Airspeed (boom)
Altitude (boom)
Total air temperature
Rotor speed
Gas generator speed **
Power turbine speed**
Engine mass fuel flow**
Engine fuel used**
Engine output shaft torque**
Turbine gas temperature**
Main rotor shaft torque
Main rotor shaft temperature
Tail rotor shaft torque
Lateral acceleration at CG (sensitive)
Stabilator position
Control positions
    Longitudinal cyclic
    Lateral cyclic
    Directional pedal
    Collective
Attitude
    Pitch
    Roll
    Heading
Linear acceleration
    Center of gravity normal
    Center of gravity lateral
    Center of gravity longitudinal
Angle of sideslip
Angle of attack
Time of day
Run number
Pilot event
Engineer event

**Both engines

27

3. Calibrations of the engine torque sensor systems in an engine test cell were not accomplished. The typical engine run sheets provided by the manufacturer for the engine were substituted for these calibrations. Figures 2 and 3 present the "calibrations" used to determine engine torque.
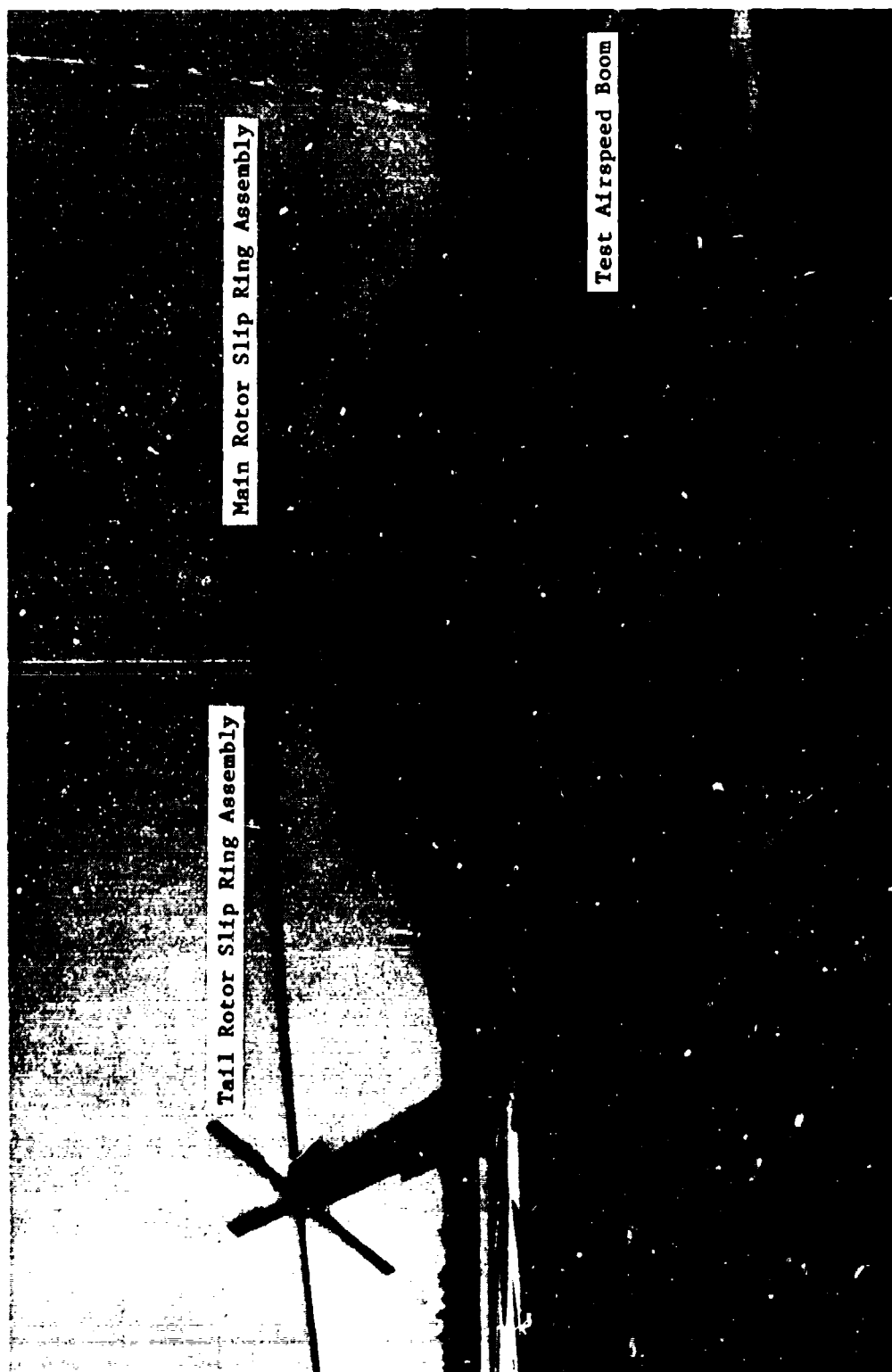
Photo 1. UH-60A ESSS External Instrumentation

29

FIGURE 1
BOOM SYSTEM AIRSPEED CALIBRATION IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	WING STORES
⊙	16,180	350.6	0.0	3500	8.5	258	FIXED PROVISIONS ONLY
☐	16,000	349.6	0.0	9680	3.5	252	MODIFIED ESSS WITH FOUR TANKS

NOTE: 1.   SHORT DASHED LINE INDICATES EXTRAPOLATED
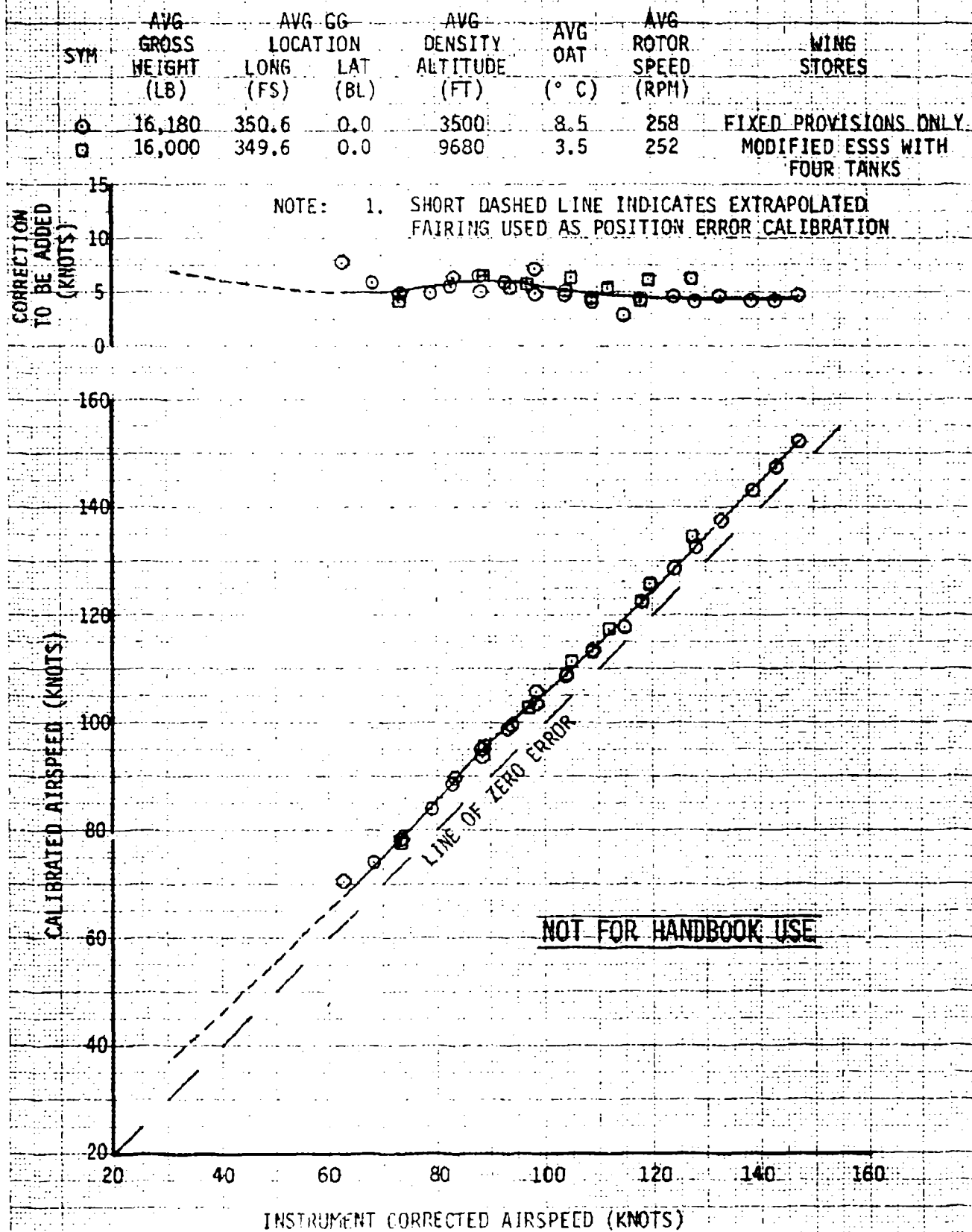FAIRING USED AS POSITION ERROR CALIBRATION

NOT FOR HANDBOOK USE

FIGURE 2
ENGINE TORQUEMETER CALIBRATION
T700-GE-700 S/N 207486

NOTES: 1. DATA OBTAINED FROM ENGINE RUN SHEETS
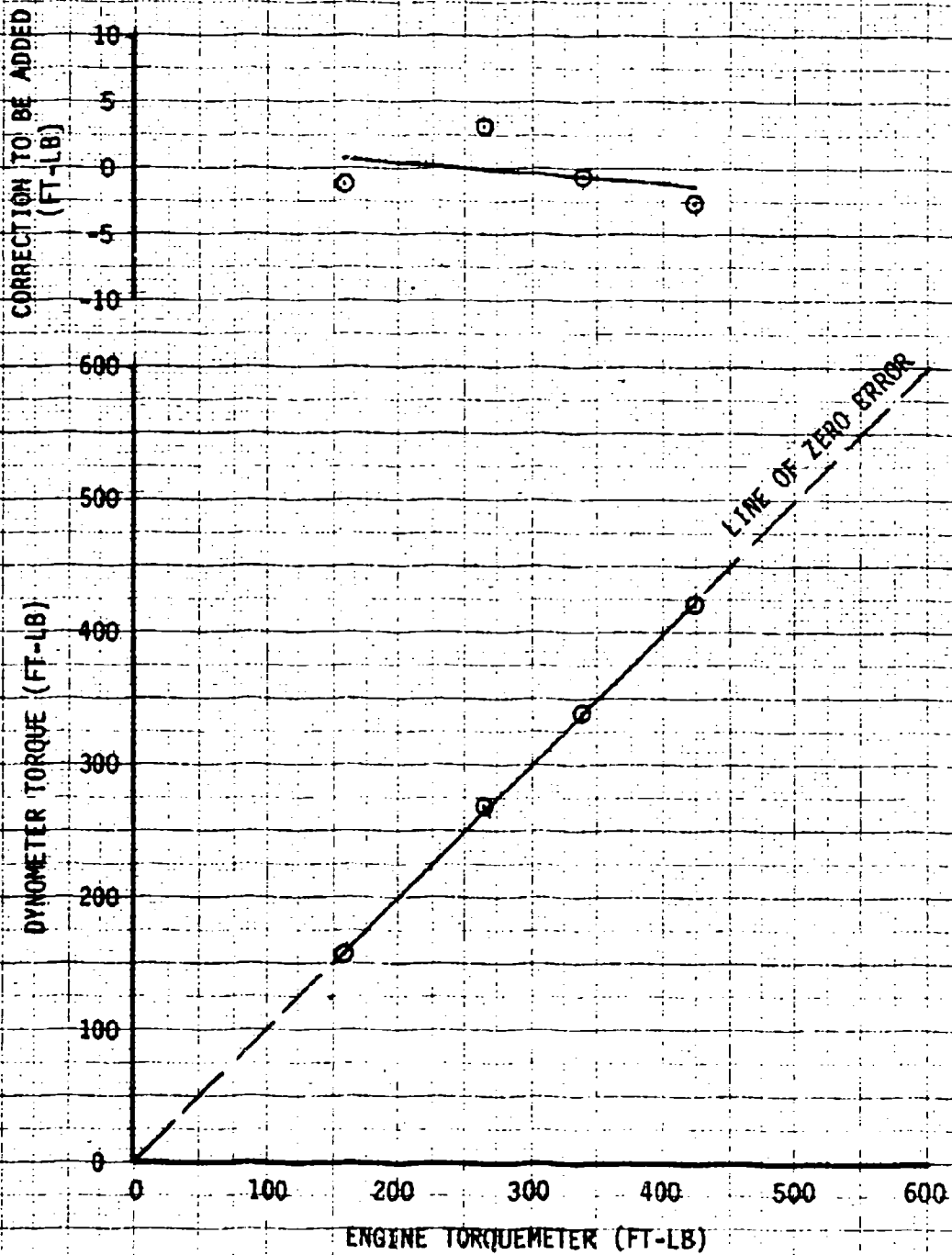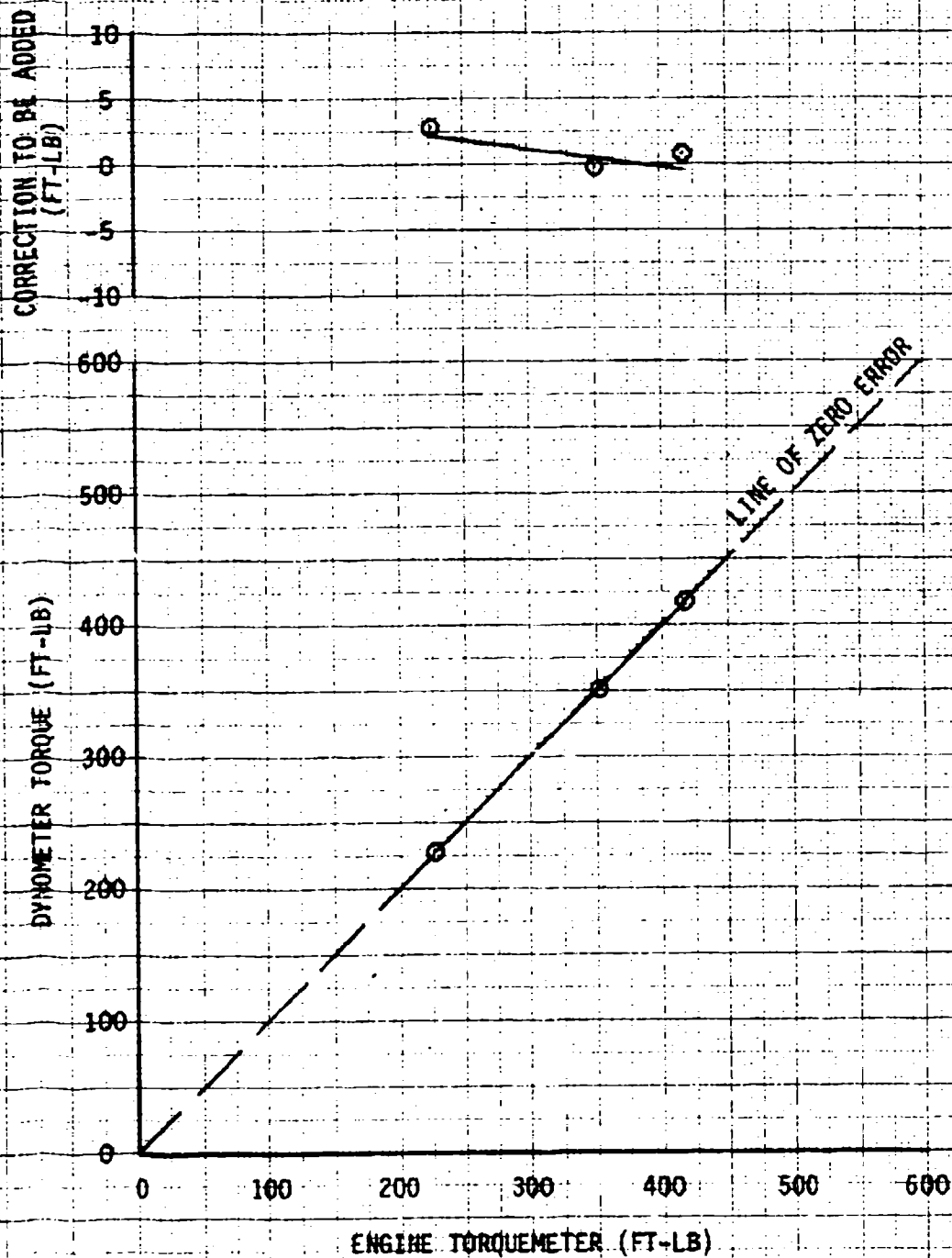2. ENGINE OUTPUT SPEED = 20,900 RPM

FIGURE 3
ENGINE TORQUEMETER CALIBRATION
T700-GE-700 S/N 306006

NOTES: 1. DATA OBTAINED FROM ENGINE RUN SHEETS
2. ENGINE OUTPUT SPEED = 20,900 RPM

CORRECTION TO BE ADDED (FT-LB)

DYNOMETER TORQUE (FT-LB)

LINE OF ZERO ERROR

ENGINE TORQUEMETER (FT-LB)

32

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

GENERAL

1. Level flight performance and control positions in level flight were obtained in coordinated (ball-centered) flight and compared with the test results of the A&FC Evaluation of the UH-60A (Black Hawk) helicopter (ref 6, app A). Referred rotor speed was maintained constant for all tests at 258 RPM. Longitudinal CG was allowed to vary ± 1.0 inch during each test flight but for each data set, (consisting of several flights in the same aircraft configuration at different thrust coefficient values) the average cg location was maintained constant near the proposed mission value. The data were analyzed to determine the power required differences between the various aircraft configurations and the A&FC in terms of changes in equivalent flat plate area (ΔF_e).

Aircraft Weight and Balance

2. The test aircraft was weighed at the start of the test program with all instrumentation installed, full oil and fuel drained in the fixed provisions configuration. The initial weight of the aircraft was 12,068 pounds with the longitudinal CG located at FS 358.9 and the lateral cg located at BL 0.2. The aircraft was weighed in several other configurations periodically during the test. It was not possible to weigh the aircraft at the 24,500 pound gross weight since the only scales available required the aircraft to be supported at its jack points. The aircraft weight at the tail jack point exceeded the 5000 pound jack point limit. The fuel cells and external sight gauges were calibrated using a calibrated flow meter. The fuel weight for each test flight was determined prior to and after each flight using these external sight gauges to determine the fuel volume and measuring the specific gravity of the fuel.

Level Flight Performance

3. The engine output shaft torque was determined by use of the engine torque sensor. The output shaft horsepower was determined from the engine output shaft torque and rotational speed by the following equation:

$$SHP = \frac{2\pi (N_p) Q}{33,000} \tag{1}$$

Where:

Q = Engine output shaft torque (ft-lb)

N_p = Engine output shaft rotational speed (RPM)

33,000 - Conversion factor (ft-lb/min)/SHP

4. The level flight performance was generalized through the use of nondimensional coefficients as follows using the 1968 U.S. standard atmosphere:

$$C_P = \frac{SHP\,(478935.3)}{\delta\sqrt{\theta}\left[\dfrac{N_R}{\sqrt{\theta}}\right]^3 \rho_o A R^3} \tag{2}$$

$$C_T = \frac{GW\,(91.19)}{\delta\left[\dfrac{N_R}{\sqrt{\theta}}\right]^2 \rho_o A R^2} \tag{3}$$

$$\mu = \frac{V_T\,(16.12)}{R\sqrt{\theta}\,\dfrac{N_R}{\sqrt{\theta}}} \tag{4}$$

Changes in engine power coefficient due to changes in flat plate area were determined using the following equation:

$$\Delta C_P = \frac{\Delta Fe\,\mu^3}{2A} \tag{5}$$

Where:

$$\delta = \text{Pressure ratio} = \frac{P_a}{P_{a_o}}$$

$\rho_0 = 0.0023769$ slugs/ft^3

A = Main rotor disk area = 2262.02 ft^2

R = Main rotor radius = 26.833

P_A = Ambient pressure in.-Hg

P_{a_0} = 29.92126 in. -Hg

θ = Temperature ratio = $\dfrac{OAT + 273.15}{288.15}$

OAT = Ambient air temperature (°C)

N_R = Main rotor speed (rev/min)

478935.3 = Conversion factor (ft-lb-sec^2 -rev^3/min^3-SHP)

91.19 = Conversion factor (sec^2-rev^2/min^2

16.12 = Conversion factor (ft-rev/min-kt)

ΔF_e = Change in equivalent flat plate area (ft^2)

μ = Advance ratio

5. Each speed power was flown in ball centered flight by reference to the ship's turn and bank indicator at a predetermined thrust coefficient (C_T) and referred rotor speed ($N_R/\sqrt{\theta}$). Both the pilot's and copilot's turn and bank indicators were checked for alignment with the aircraft positioned in a level attitude. To maintain the ratio of gross weight to pressure ratio (W/δ) constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant, rotor speed was varied as appropriate for the ambient air temperature. Corrections to power required were made for the installation of test instrumentation. The power consumption for the electrical operation of the instrumentation equipment was measured and determined to be 2.73 SHP and subtracted from the power required data. The effects of the external instrumentation and nonstandard aircraft equipment were estimated by SA to be the equivalent of 3.68 ft^2 of flat plate area. Paragraph 5, appendix B, lists the items included for this estimate.

35

6. Test-day level flight data was corrected to standard day conditions by the following equations:

$$ SHP_s = SHP_t \frac{(\delta_s \sqrt{\theta_s}) \left[\dfrac{N_R}{\sqrt{\theta}} \right]_s^3}{(\delta_t \sqrt{\theta_t}) \left[\dfrac{N_R}{\sqrt{\theta}} \right]_t^3} \tag{6} $$

$$ V_{T_s} = V_{T_t} \frac{\left[\dfrac{N_R}{\sqrt{\theta}} \right]_s}{\left[\dfrac{N_R}{\sqrt{\theta}} \right]_t} \tag{7} $$

Where:

Subscribt t = Test day

Subscript s = Standard day

Test data corrected for instrumentation drag and corrected to standard altitude and ambient temperature are presented in figures 3 through 6, 11 through 15, 20 through 23 and 28 through 32 appendix E.

7. The data obtained for three configurations (the original ESSS with two and four fuel tanks installed and the modified ESSS with four fuel tanks) were analyzed by use of a three dimensional plot for each configuration. The power required data was plotted as a function of airspeed in terms of C_p versus μ at a constant C_T. These curves were then joined by lines of constant μ to form the carpet plot. The reduction of this carpet plot to a family of curves of C_T versus C_p, for a constant μ value, allows determination of the power required as a function of airspeed for any value of C_T. Except for one flight at a $C_T = 0.009033$ in the modified ESSS with four fuel tank configuration, longitudinal cg was maintained constant within each data set. For use in the carpet plot the power required data for this one flight was reduced by an amount, using equation 5, where

36

ΔF_e = 1.1 ft^2. This value was estimated from data available in the A&FC final report (ref 6, app A). The data obtained for the rest of the configurations tested (the original ESSS with no stores, original ESSS with four fuel tanks with the aircraft longitudinal cg at FS 343.0 and the fixed provisions) were analyzed by calculating an equivalent flat plat area change between the data points and a baseline fairing using equation 5.

8. The baseline fairing used to determine the difference between the fixed provisions configuration data and the normal utility configuration data of the A&FC consisted of three elements. The nondimensional data of the A&FC final report (ref 6, app A) at $N_R/\sqrt{\theta}$ = 258 RPM was used as the starting point. Then the power required data was corrected from a zero sideslip trim condition of this data plot to ball-centered trim conditions by using the inherent sideslip of the PAE test aircraft (figs. 33 and 34, app E). The power required due to sideslip relationship was assumed to be the same as that found for the A&FC test aircraft. Figure 46, appendix E, of the A&FC final report (ref 6, app A) was used to correct this data. Finally, a power required increase equivalent to ΔF_e = 0.5 ft^2 (estimated by the SA) was added because of an infrared jammer and chaff dispenser mounting bracket installed on the PAE test aircraft but not included in the A&FC test aircraft normal utility configuration. These are part of the proposed self deployment ferry mission. The following equation illustrates the components that determined the baseline for the fixed provisions configuration:

$$C_{P_{F.P. \text{ Baseline}}} = C_{P_{A\&FC}} + C_{P_{\text{sideslip PAE}}} + C_{P_{IR \text{ Jammer}}} \quad (8)$$

Where:

$C_{P_{F.P. \text{ Baseline}}}$ = Baseline power coefficient for fixed provisions only configuration

$C_{P_{A\&FC}}$ = A&FC power coefficient at zero sideslip trim condition

$C_{P_{\text{sideslip PAE}}}$ = Power coefficient for conversion from zero sideslip to ball-centered trim condition, based on PAE sideslip data

$C_{P_{IR \text{ Jammer}}}$ = Power coefficient for infrared jammer and chaff dispenser mounting bracket not included in A&FC normal utility configuration

37

The difference between this baseline and the flight test data for the fixed provisions configuration was expected to be 0.78 ft^2 of equivalent flat plate area (estimated by SA). The test results showed a ΔF_e in excess of the expected amount and to be dependent on airspeed (fig. 2, app E). A line was faired through all the fixed provisions data to represent a partially unexplained difference between the two test aircraft. This fairing was used as one of the factors in determining a baseline for the rest of the data obtained in the remaining aircraft configurations.

9. Up to six elements were used to determine a baseline for the data obtained in the ESSS only, original ESSS with two and four fuel tank, and modified ESSS with four fuel tank configurations. The first three elements were the same as those described in paragraph 8 (i.e. $C_{P_{A\&FC}}$, $\Delta C_{P_{sideslip\ PAE}}$ and $\Delta C_{P_{IR\ Jammer}}$). Then the fairing through the data in figure 2, appendix E was applied to correct for the difference between the A&FC and the PAE level flight power required. Next, the drag estimate 0.78 ft^2 for the fixed provisions configuration was subtracted since the fixed provisions fairings are not used with any of the ESSS configurations and this estimate is included in the $C_{P_{A\&FC-PAE}}$ term (para 8). The sixth element was an estimate for the difference in longitudinal cg location of the test data with the A&FC carpet plot (FS 347.0). This was applied as appropriate for each data set. The following equation shows the six elements that are included in the baseline for these data sets.

$$C_{P_{baseline}} = C_{P_{A\&FC}} + C_{P_{sideslip\ PAE}} + C_{P_{IR\ Jammer}} + C_{P_{A\&FC-PAE}} - C_{P_{0.78}} + C_{P_{\Delta cg}} \qquad (9)$$

Where:

$C_{P_{baseline}}$ = Baseline power coefficient that includes all necessary corrections to compare similar data between the A&FC and PAE test results

$C_{P_{A\&FC}}$ = Same as described in paragraph 8

$C_{P_{sideslip\ PAE}}$ = Same as described in paragraph 8

$C_{P_{IR\ Jammer}}$ = Same as described in paragraph 8

38

$C_{P_{A\&FC-PAE}}$ =. Power coefficient attributed to difference between A&FC and PAE data.

$C_{P_{0.78}}$ = Power coefficient determined for fixed provisions drag estimate of $\Delta Fe = 0.78$ ft^2

$C_{P_{\Delta CG}}$ = Power coefficient determined for aircraft cg location difference

10. The specific range (SR) data for each level flight performance test were derived from the test level flight power required and fuel flow (W_{F_t}). Selected level flight performance SHP and fuel flow data for each engine were referred as follows:

$$SHP_{REF} = \frac{SHP_t}{\delta\theta^{0.5}} \tag{10}$$

$$W_{F_{REF}} = \frac{W_{F_t}}{\delta\theta^{0.55}} \tag{11}$$

A curve fit was subsequently applied to this referred data and was used as the basis to correct W_{F_t} to standard day fuel flow using the following equation.

$$W_{F_s} = W_{F_t} + \Delta W_F \tag{12}$$

Where:

ΔW_F = Change in fuel flow between SHP_t and SHP_s

The following equation was used for determination of specific range.

$$SR = \frac{V_{T_s}}{W_{F_s}} \tag{13}$$

APPENDIX E. TEST DATA

INDEX

FIGURE 1
SUMMARY OF DRAG CHANGE FOR VARIOUS CONFIGURATIONS
AT ADVANCE RATIO = 0.28
UH-60A   USA   S/N 77-22714

SYMBOL	CONFIGURATION	LONGITUDINAL CG LOCATION (FS)
⊙	FIXED PROVISIONS	347.0
⊡	ORIGINAL ESSS WITH NO STORES	347.0
◇	ORIGINAL ESSS WITH TWO TANKS	347.0
△	MODIFIED ESSS WITH FOUR TANKS	350.0
▽	ORIGINAL ESSS WITH FOUR TANKS	350.0

NOTES:
1. BALL-CENTERED TRIM CONDITION
2. DATA OBTAINED FROM FIGURES 2 THROUGH 32
3. BASELINE ($\Delta F_e = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE PAE TEST AIRCRAFT (INHERENT SIDESLIP AND CONFIGURATION DIFFERENCES)
4. A&FC DATA OBTAINED FROM USAAEFA TEST REPORT PROJECT 77-17

Y-axis: CHANGE IN EQUIVALENT FLAT PLATE AREA (FT²), ΔF_e

X-axis: THRUST COEFFICIENT, $C_T \times 10^4$

MODIFIED ESSS WITH FOUR TANKS

ORIGINAL ESSS WITH FOUR TANKS

ORIGINAL ESSS WITH TWO TANKS

ORIGINAL ESSS WITH NO STORES
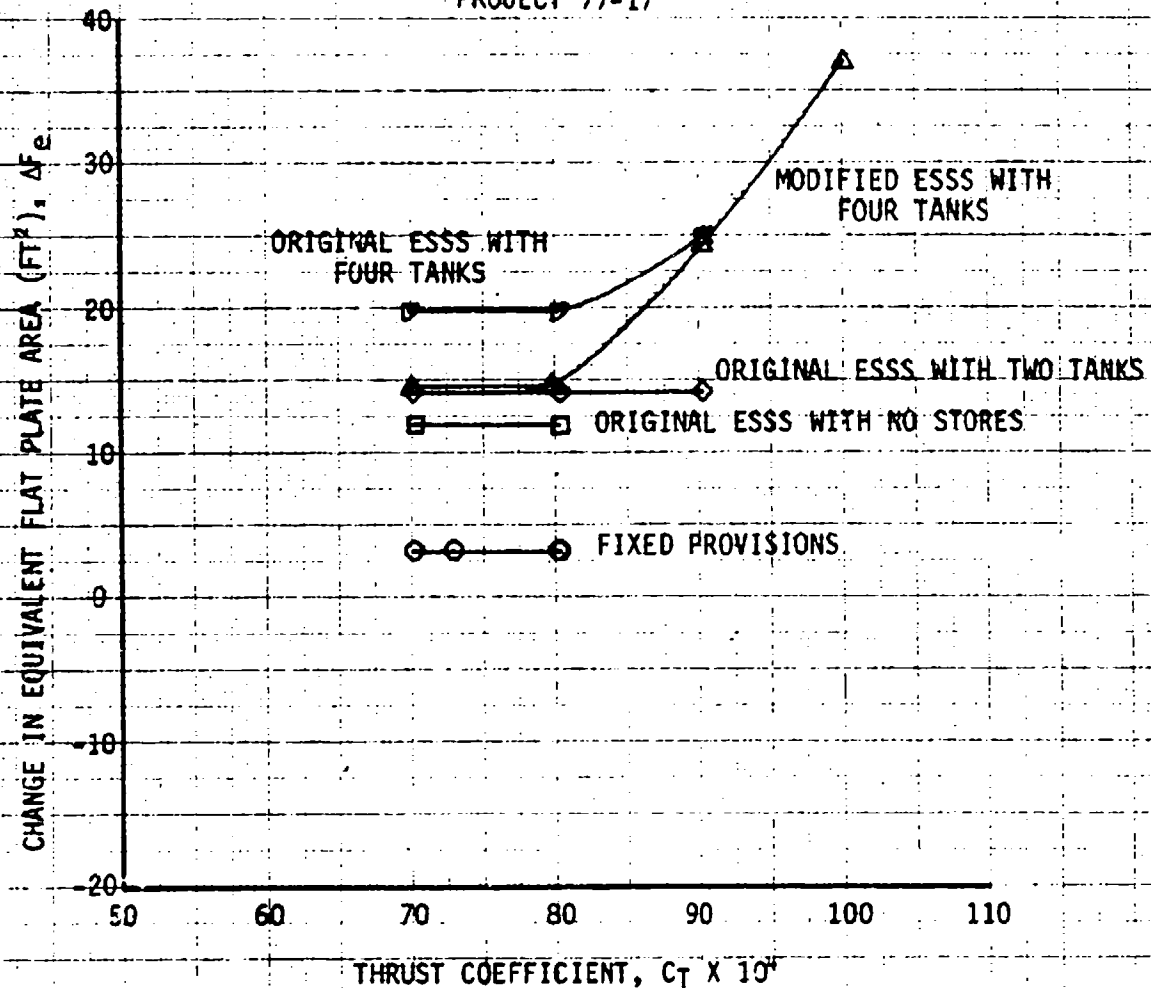
FIXED PROVISIONS

FIGURE 2
SUMMARY OF DRAG DIFFERENCE
BETWEEN PAE TEST AIRCRAFT AND A&FC TEST RESULTS
UH-60A USA S/N 77-22714

CONFIGURATION	LONGITUDINAL CG LOCATION (FS)	THRUST COEFFICIENT x 10⁴
	347.2	70.20
FIXED	347.3	72.86
PROVISIONS	346.8	80.10
	346.7	80.14

NOTES:
1. FAIRING DERIVED FROM FIGURES 3 THROUGH 6
2. BALL CENTERED TRIM CONDITION
3. BASELINE ($\Delta F_e = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP AND CONFIGURATION DIFFERENCES)
4. A&FC DATA OBTAINED FROM USAAEFA TEST REPORT PROJECT 77-17

CHANGE IN EQUIVALENT FLAT PLATE AREA (FT²), ΔF_e

40
30
20
10
0
-10
-20

ADVANCE RATIO

0.08 0.12 0.16 0.20 0.24 0.28 0.32 0.36

FIGURE 3
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10^4	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
16,040	347.2	0.2R	6580	11.0	257.8	70.20	FIXED PROVISIONS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM FIGURES 33 AND 34

FAIRING DERIVED FROM A&FC TEST REPORT 77-17 AND FIGURE 2

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

SPECIFIC RANGE (NAUT AIR MILES PER POUND OF FUEL)

ENGINE SHAFT HORSEPOWER (SHP)

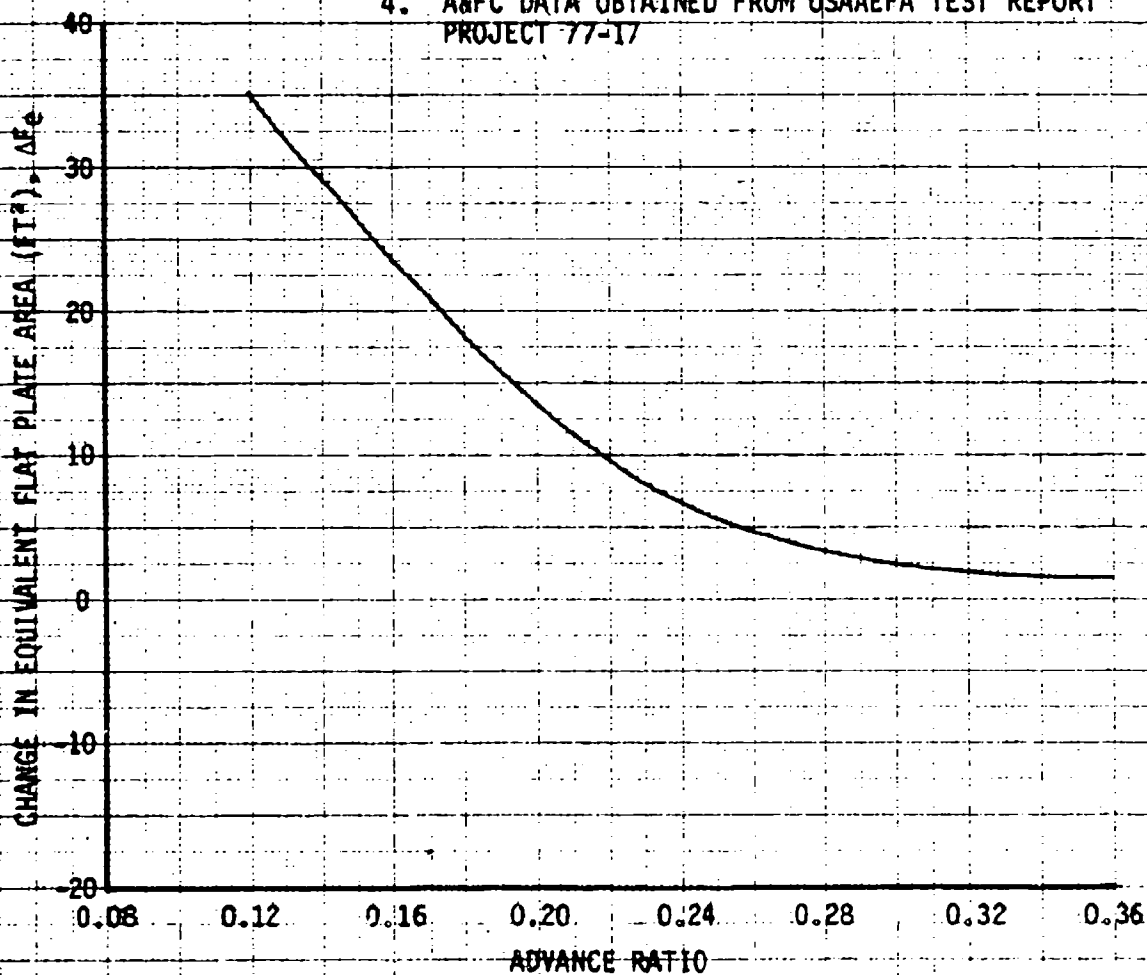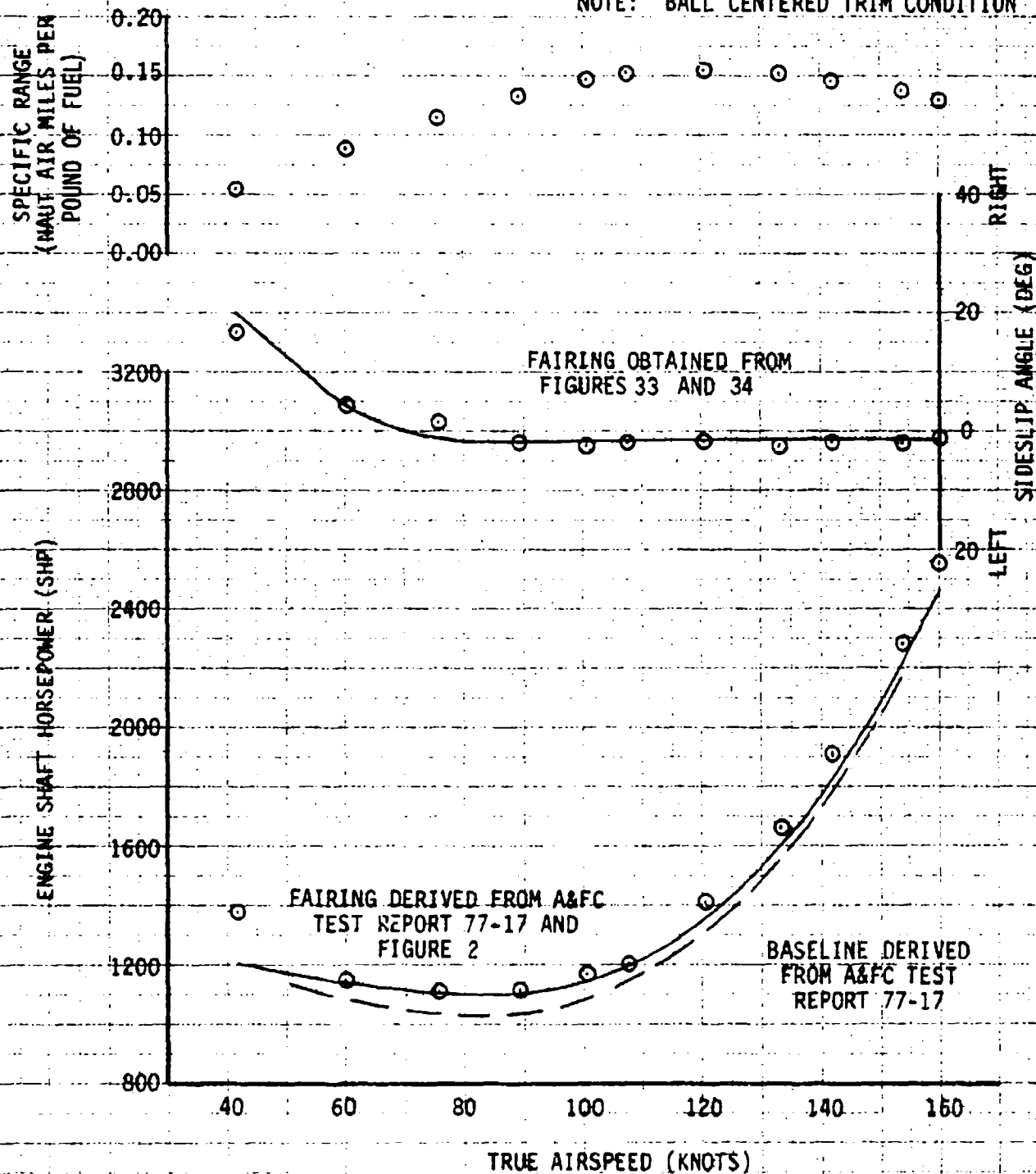SIDESLIP ANGLE (DEG)

TRUE AIRSPEED (KNOTS)

43

FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
16,100	347.3	0.0	7660	10.5	258.0	72.86	FIXED PROVISIONS

NOTE: 1. BALL CENTERED TRIM CONDITION
2. THE BOOM SYSTEM WAS USED AS THE AIRSPEED SOURCE FOR THE NO. 2 STABILATOR AMPLIFIER
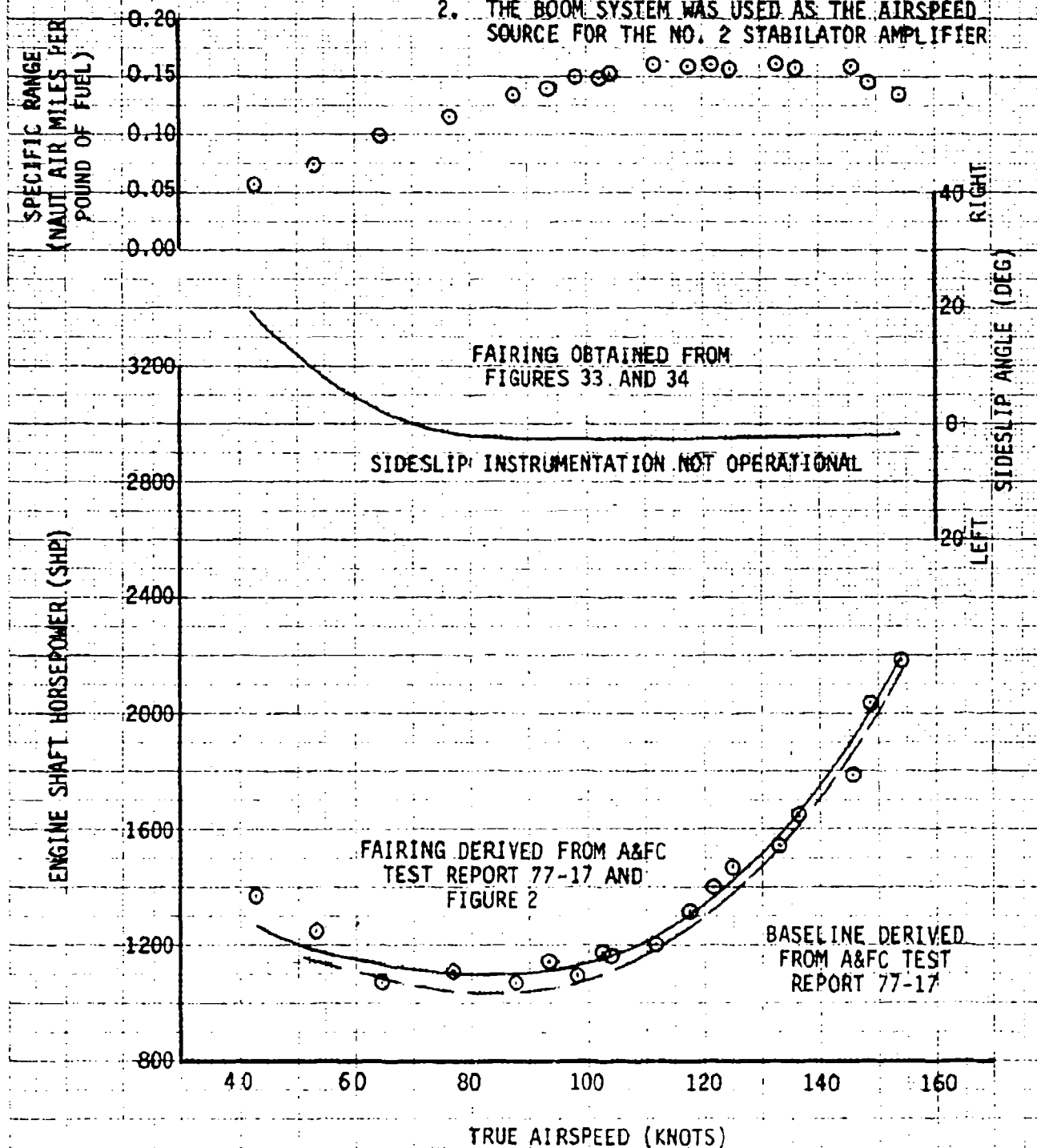

FAIRING OBTAINED FROM FIGURES 33 AND 34

SIDESLIP INSTRUMENTATION NOT OPERATIONAL

FAIRING DERIVED FROM A&FC TEST REPORT 77-17 AND FIGURE 2

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

TRUE AIRSPEED (KNOTS)

44

FIGURE 5
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
18,000	346.8	0.2R	6880	8.5	257.9	80.10	FIXED PROVISIONS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM FIGURES 33 AND 34

FAIRING DERIVED FROM A&FC TEST REPORT 77-17 AND FIGURE 2

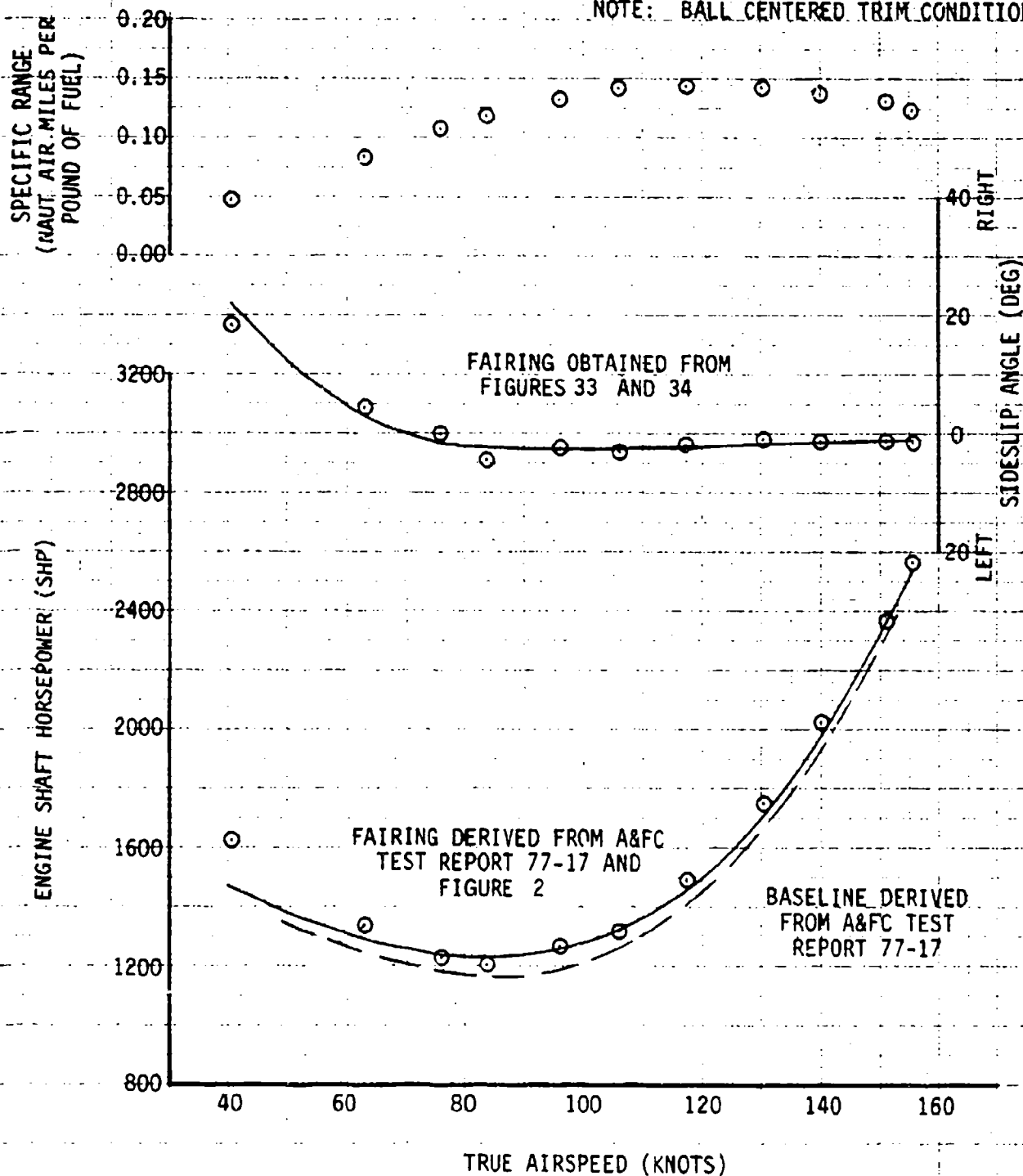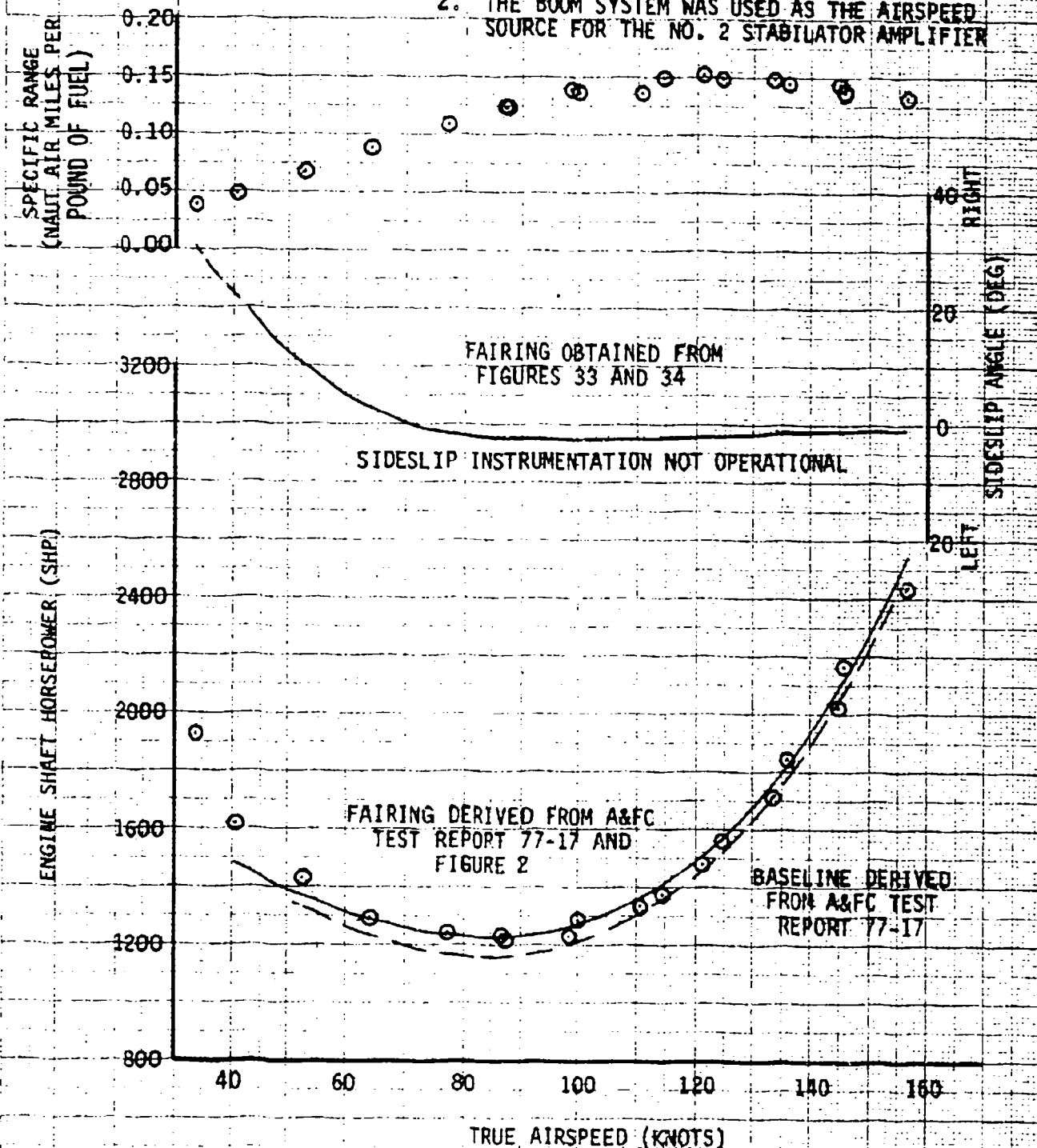BASELINE DERIVED FROM A&FC TEST REPORT 77-17

45

FIGURE 6
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIGURATION
	LONG (FS.)	LAT (BL)					
17,840	346.7	0.0	7680	13.0	257.9	80.14	FIXED PROVISIONS

NOTE: 1. BALL CENTERED TRIM CONDITION
2. THE BOOM SYSTEM WAS USED AS THE AIRSPEED SOURCE FOR THE NO. 2 STABILATOR AMPLIFIER

FAIRING OBTAINED FROM FIGURES 33 AND 34

SIDESLIP INSTRUMENTATION NOT OPERATIONAL

FAIRING DERIVED FROM A&FC TEST REPORT 77-17 AND FIGURE 2

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

46

FIGURE 7

DRAG CHANGE SUMMARY FOR ORIGINAL ESSS WITH FOUR TANKS
UH-60A   USA   S/N 77-22714

CONFIGURATION	LONGITUDINAL CG LOCATION (FS)	THRUST COEFFICIENT x 10⁴
ORIGINAL ESSS	349.7	69.91
WITH FOUR TANKS	350.2	80.23
	349.8	90.18

NOTES:
1. BALL CENTERED TRIM CONDITION
2. FAIRINGS DERIVED FROM FIGURES 8, 9 AND 10
3. BASELINE ($\Delta F_e = 0$) IS THE AEFC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP, CONFIGURATION DIFFERENCES, LONGITUDINAL CG AND UNEXPLAINED ΔF_e DIFFERENCE, FIGURE 2)
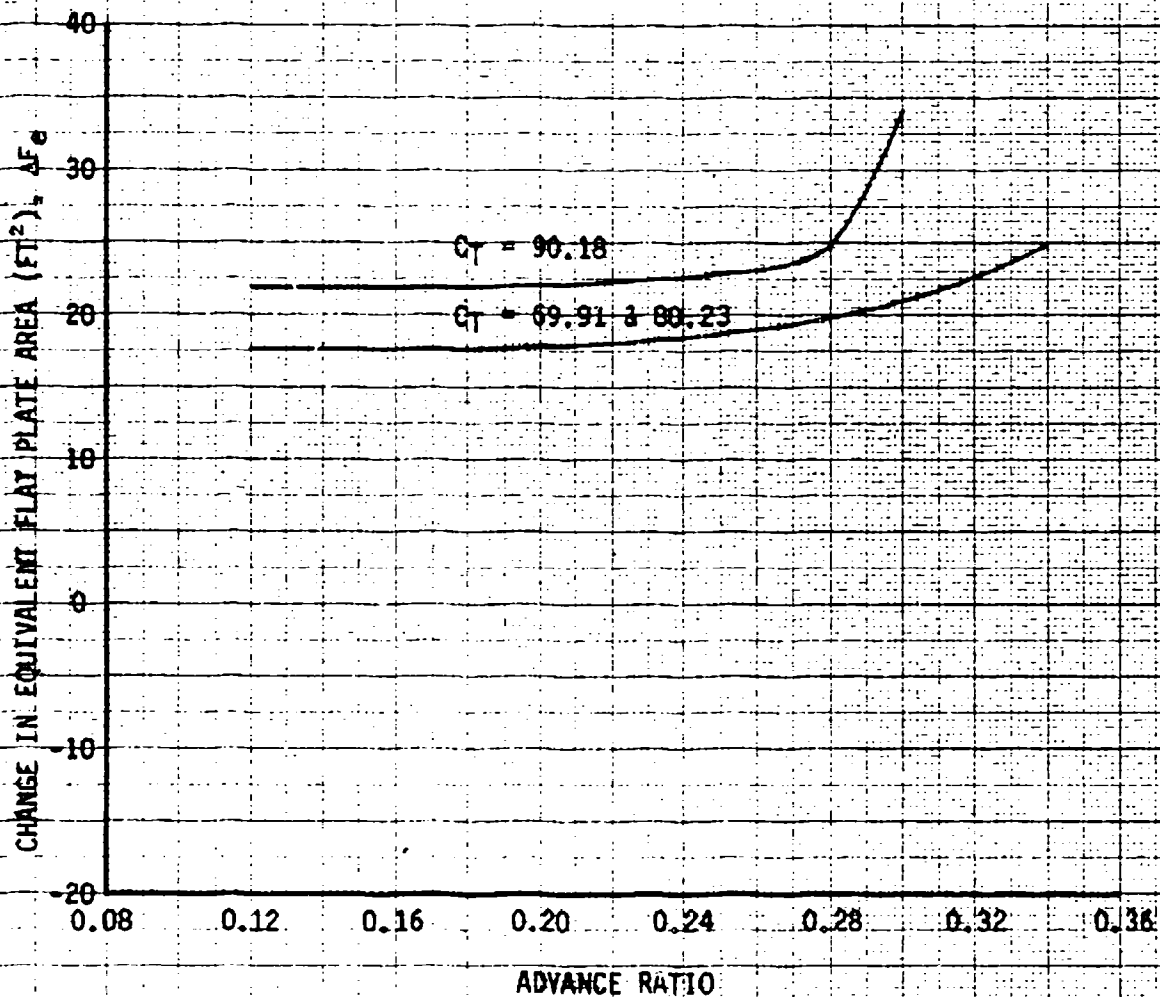
$C_T = 90.18$

$C_T = 69.91$ & 80.23

CHANGE IN EQUIVALENT FLAT PLATE AREA (FT²), ΔF_e

ADVANCE RATIO

FIGURE 8
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH FOUR TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 350.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 11 THROUGH 15

FIGURE 9
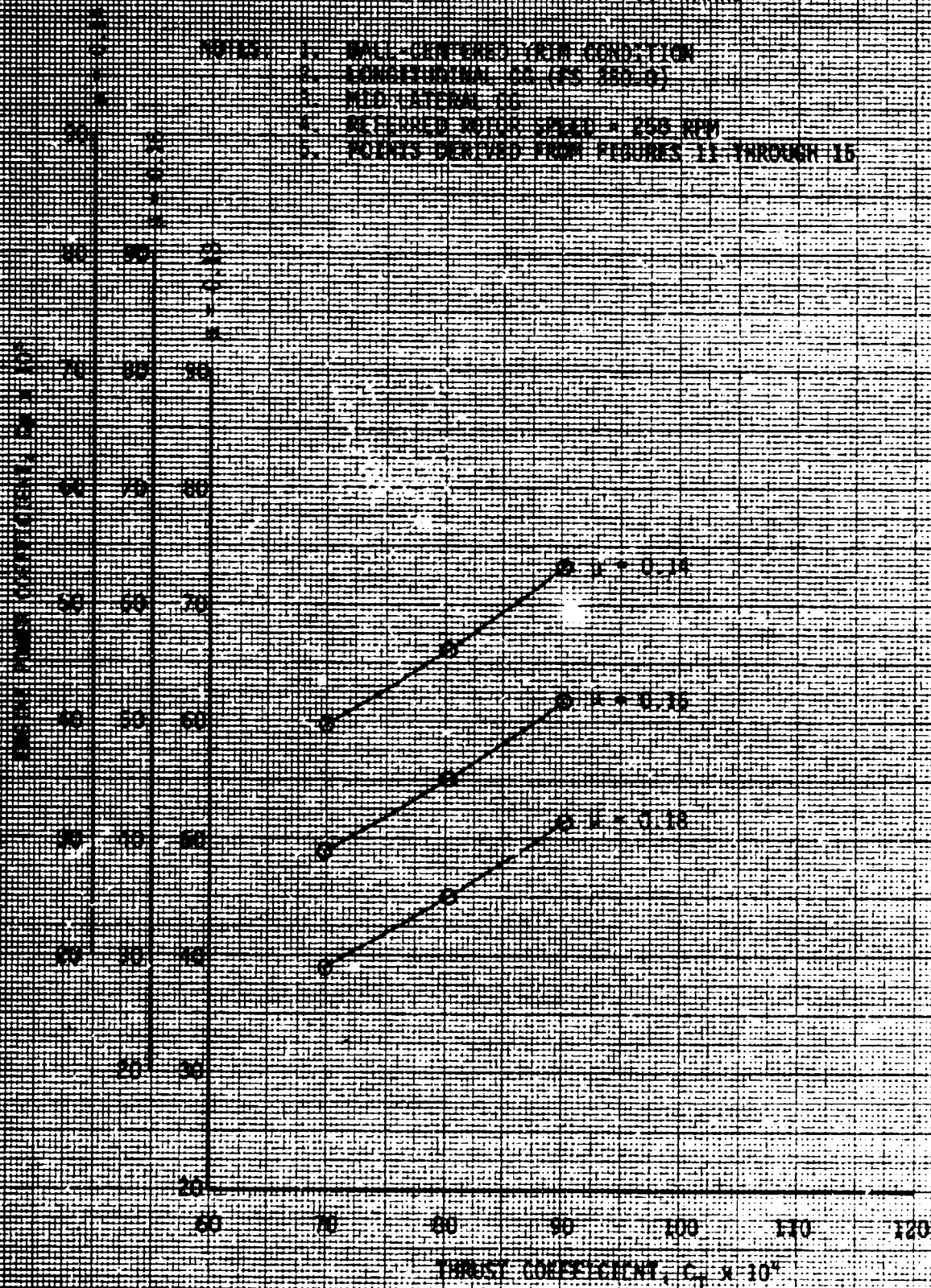
FIGURE 10
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22716

CONFIGURATION: ORIGINAL ESSS WITH FOUR TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 350.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
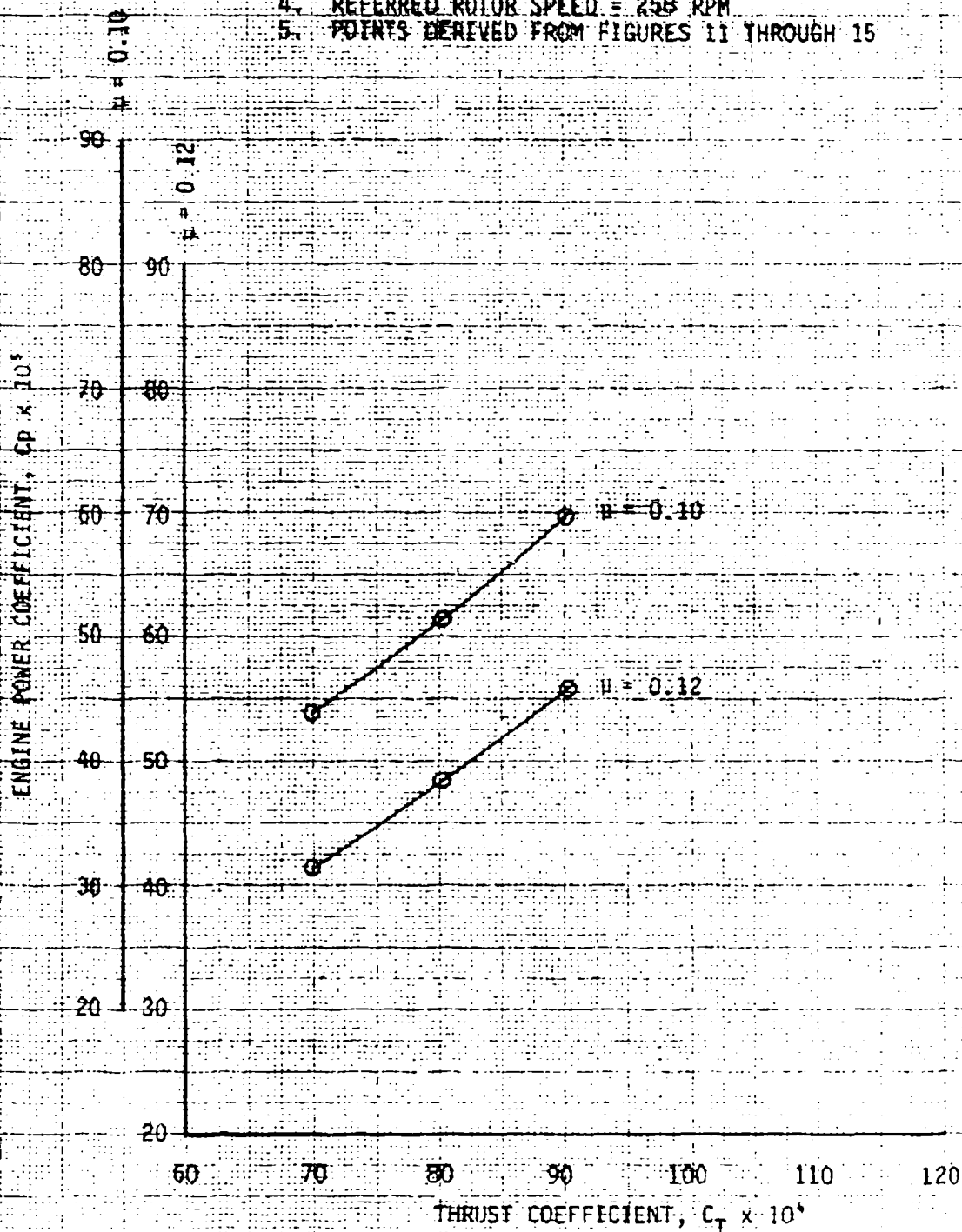5. POINTS DERIVED FROM FIGURES 11 THROUGH 15

FIGURE 11
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
16,000	349.7	0.0	6540	10.0	258.3	69.92	ORIGINAL ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FIGURE 12
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

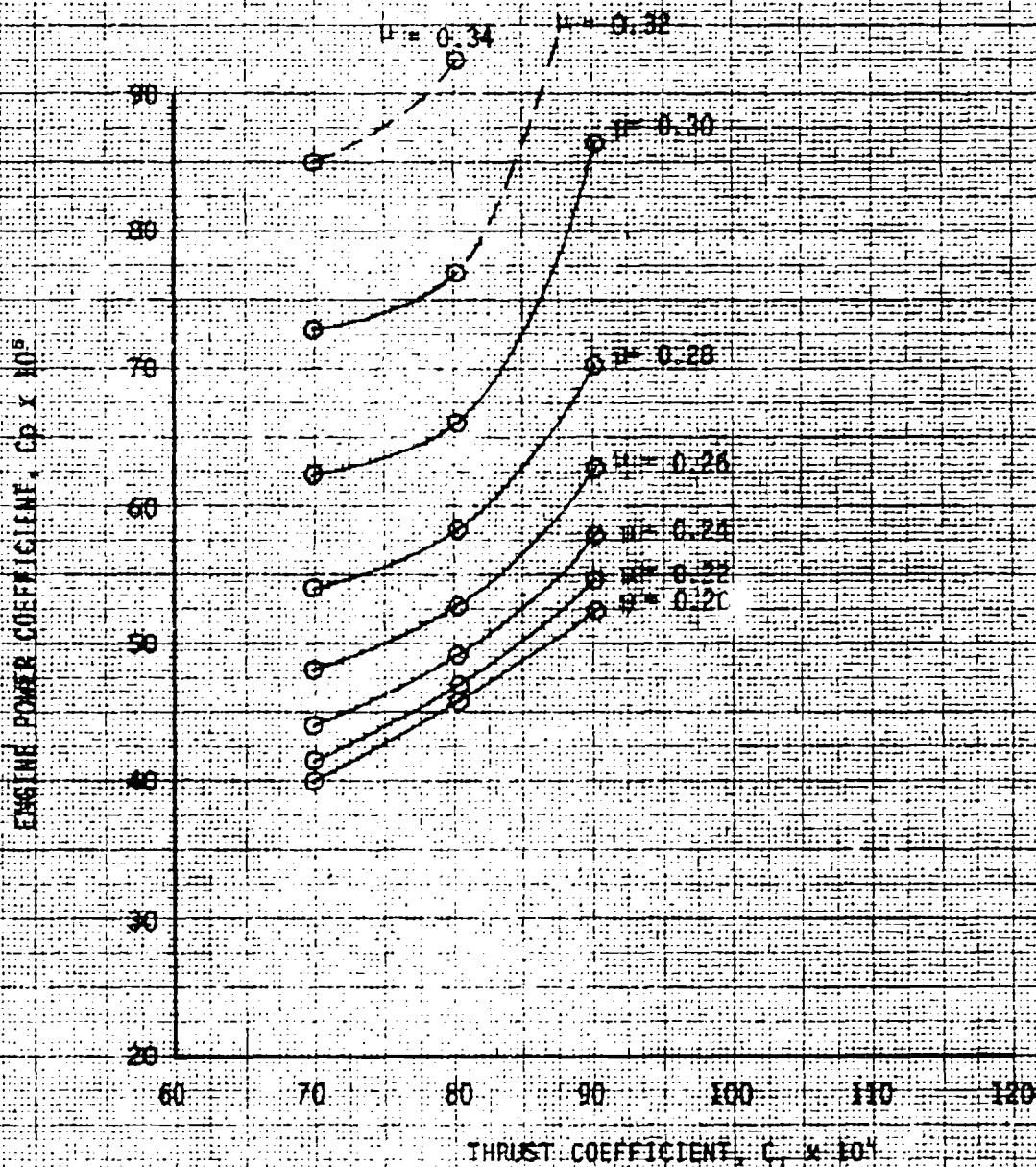| AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (° C)	AVG REFERRED ROTOR SPEED (RPM)	AVG CT x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
16,040	350.2	0.2	10,380	7.5	257.4	80.23	ORIGINAL ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

SPECIFIC RANGE (NAUT AIR MILES PER POUND OF FUEL)

0.20
0.15
0.10
0.05
0.00

RIGHT 40
SIDESLIP ANGLE (DEG)
20
0
LEFT 20

FAIRING OBTAINED FROM FIGURES 33 AND 34

3200
2800

ENGINE SHAFT HORSEPOWER (SHP)

2400
2000
1600

FAIRING DERIVED FROM FIGURES 8 THROUGH 10

1200

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

800

20   40   60   80   100   120   140

TRUE AIRSPEED (KNOTS)

FIGURE 13
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10^4	AIRCRAFT CONFIGURATION
17,960	349.8	0.2	10,740	8.5	257.9	90.18	ORIGINAL ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

SPECIFIC RANGE (NAUT AIR MILES PER POUND OF FUEL)

FAIRING OBTAINED FROM FIGURES 33 AND 34

SIDESLIP ANGLE (DEG)   RIGHT   LEFT

ENGINE SHAFT HORSEPOWER (SHP)

FAIRING DERIVED FROM FIGURES 8 THROUGH 10

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

TRUE AIRSPEED (KNOTS)
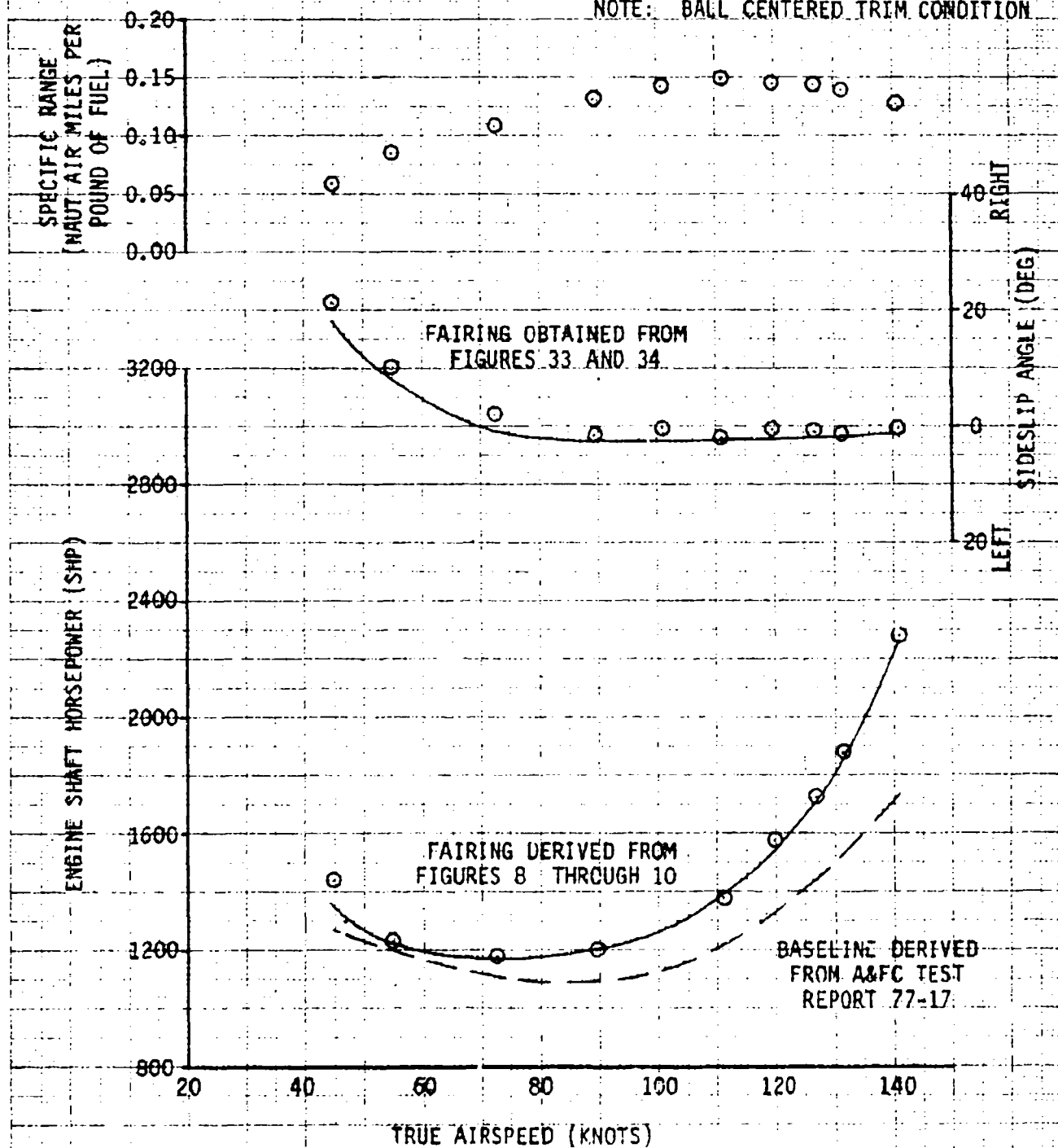
53

FIGURE 14
LEVEL FLIGHT PERFORMANCE
UH-60A   USA   S/N 77-22714

| AVG GROSS WEIGHT (LB) | AVG CG LOCATION | | AVG DENSITY ALTITUDE (FT) | AVG OAT (°C) | AVG REFERRED ROTOR SPEED (RPM) | AVG CT × 10⁴ | AIRCRAFT CONFIGURATION |
	LONG (FS)	LAT (BL)					
17,960	343.0(FWD)	0.2R	10,740	7.5	258.4	90.15	ORIGINAL CASS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM
FIGURES 33 AND 34

FAIRING DERIVED FROM
FIGURES 8 THROUGH 10
CORRECTED TO FS 343.0
(1.2 FT² ΔFe)

BASELINE DERIVED FROM A+EC
TEST REPORT 77-17 CORRECTED
TO FS 360.0 (0.7 FT² ΔFe)

SPECIFIC RANGE (NAUTICAL MILES PER POUND OF FUEL)

ENGINE SHAFT HORSEPOWER (SHP)

SIDESLIP ANGLE (DEG)
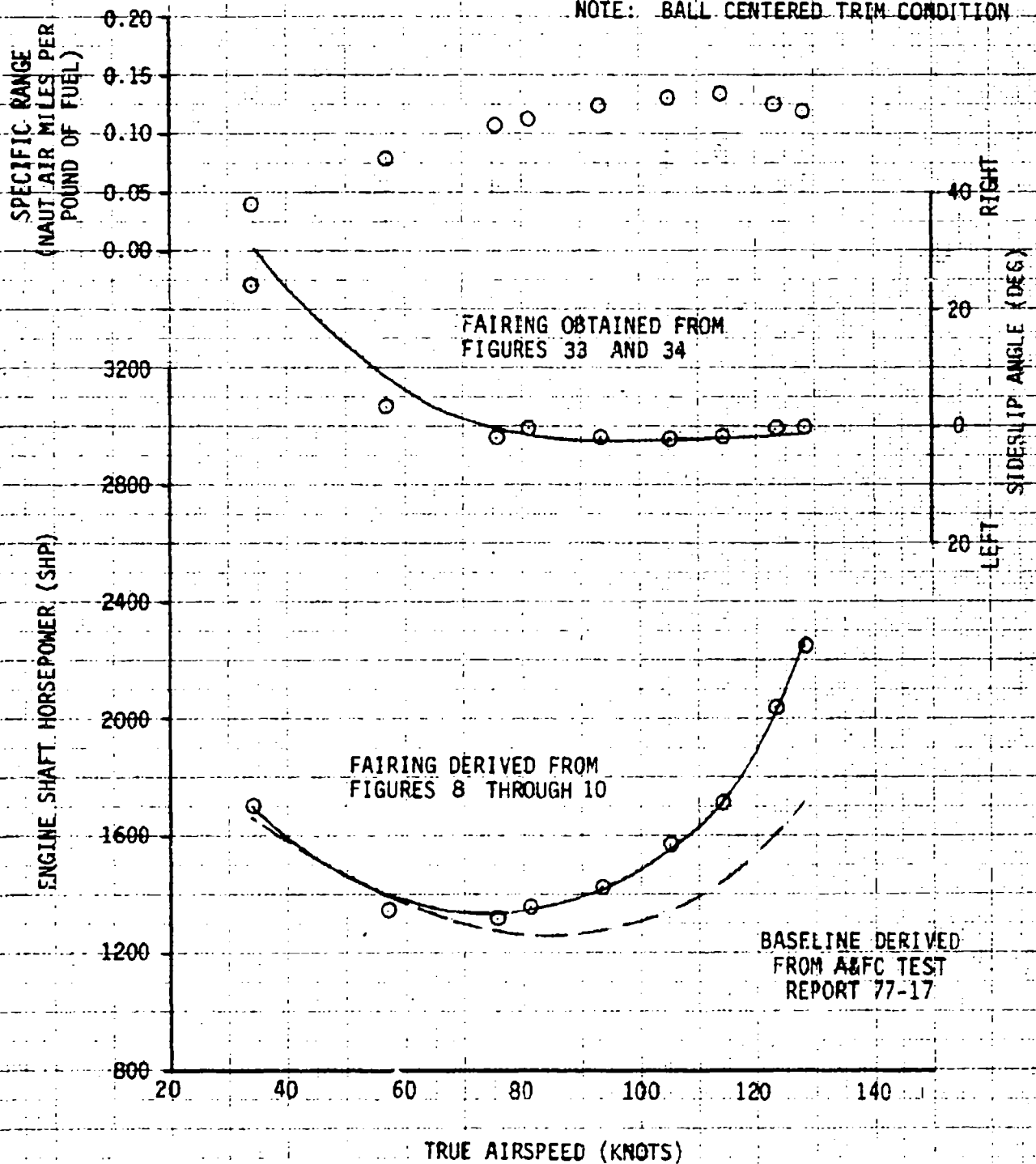
TRUE AIRSPEED (KNOTS)

FIGURE 35
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

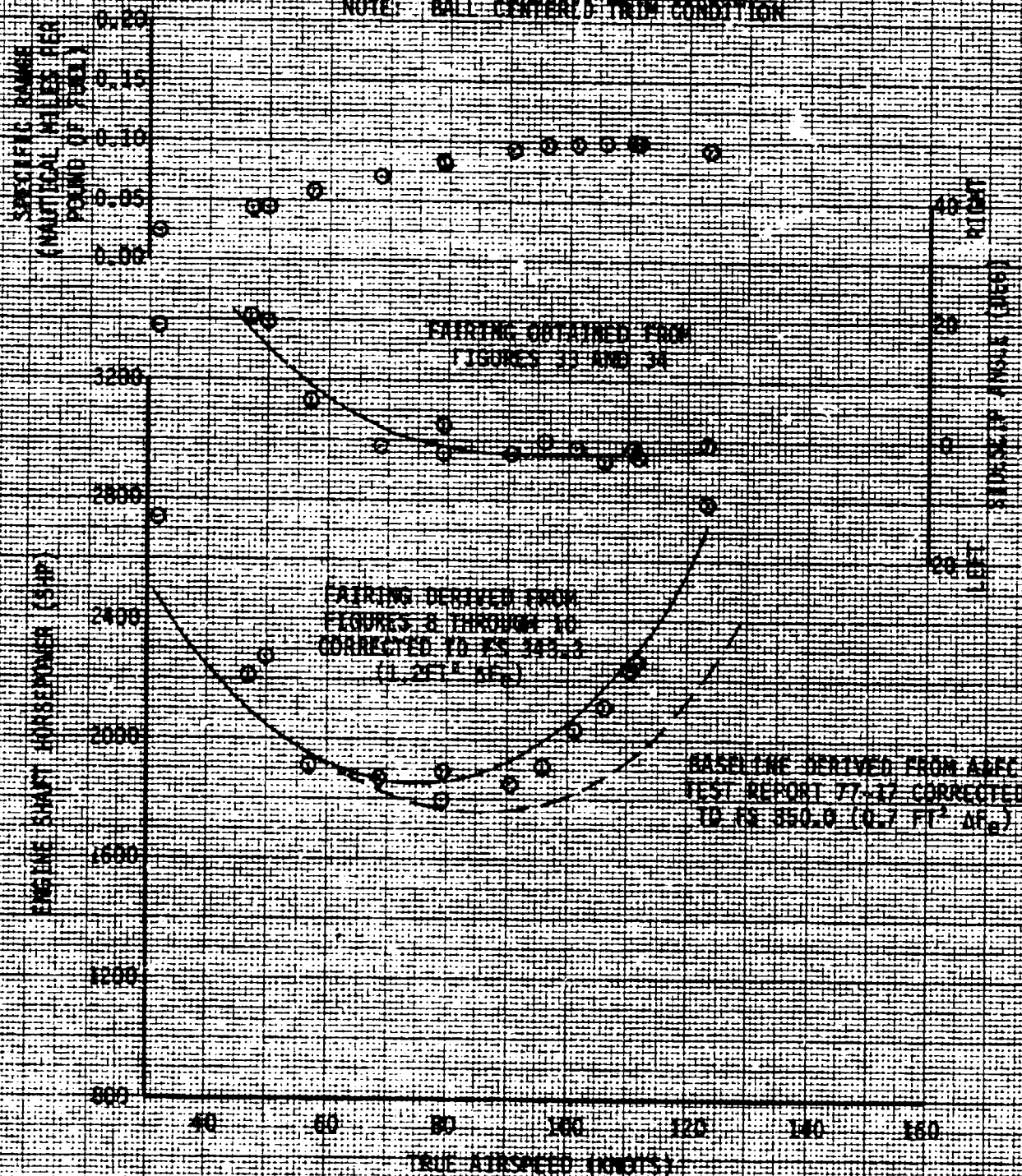| AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIGURATION
	FWD (FS)	LAT (BL)					
24,580	348.3(FWD)	0.2R	1380	16.5	257.3	90.60	ORIGINAL ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FIGURE 16
DRAG CHANGE SUMMARY FOR MODIFIED ESSS WITH FOUR TANKS
UH-60A USA S/N 77-22714

CONFIGURATION	LONGITUDINAL CG LOCATION (FS)	THRUST COEFFICIENT X 10^4
MODIFIED ESSS WITH FOUR TANKS	349.9	70.08
	350.0	79.86
	350.0	90.38
	350.3	100.16

NOTES:
1. BALL CENTERED TRIM CONDITION
2. FAIRINGS DERIVED FROM FIGURES 17, 18 AND 19
3. BASELINE ($\Delta F_e = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP, CONFIGURATION DIFFERENCES, LONGITUDINAL CG AND UNEXPLAINED ΔF_e DIFFERENCE, FIGURE 2)
4. DATA AT C_T = 90.33 CORRECTED FOR CG DIFFERENCE TO FS 350.0

CHANGE IN EQUIVALENT FLAT PLATE AREA (FT^2), ΔF_e

C_T = 100.16

C_T = 90.33

C_T = 70.08 & 79.86

ADVANCE RATIO

FIGURE 17
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: MODIFIED ESSS WITH FOUR TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 350.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 20 THROUGH 23

FIGURE 18
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: MODIFIED ESSS WITH FOUR TANKS

NOTES: 1.   BALL-CENTERED TRIM CONDITION
         2.   LONGITUDINAL CG (FS 350.0)
         3.   MID LATERAL CG
         4.   REFERRED ROTOR SPEED = 258 RPM
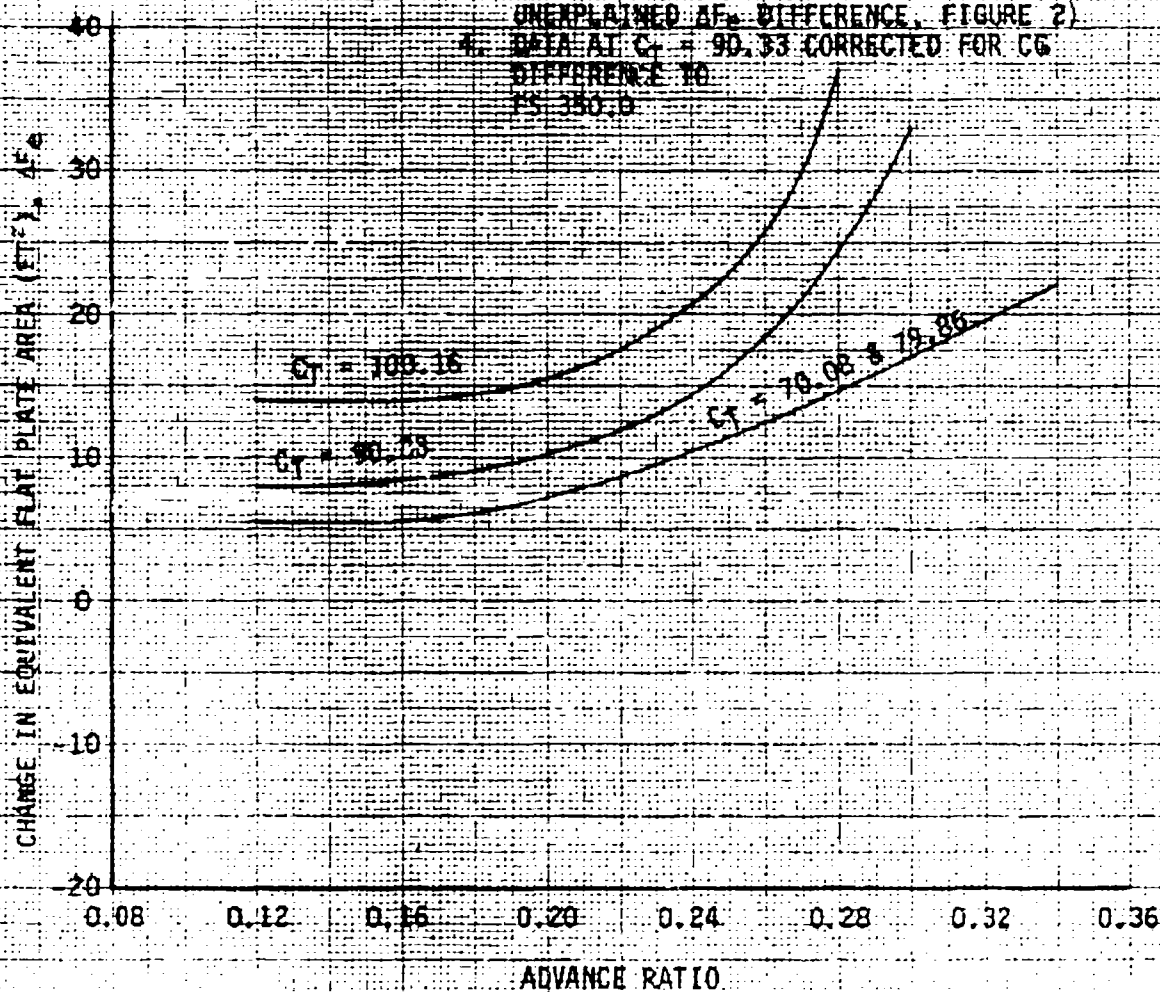   5.   POINTS DERIVED FROM FIGURES 20 THROUGH 23

FIGURE 19
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: MODIFIED ESSS WITH FOUR TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
        2. LONGITUDINAL CG (FS 350.0)
        3. MID LATERAL CG
        4. REFERRED ROTOR SPEED = 258 RPM
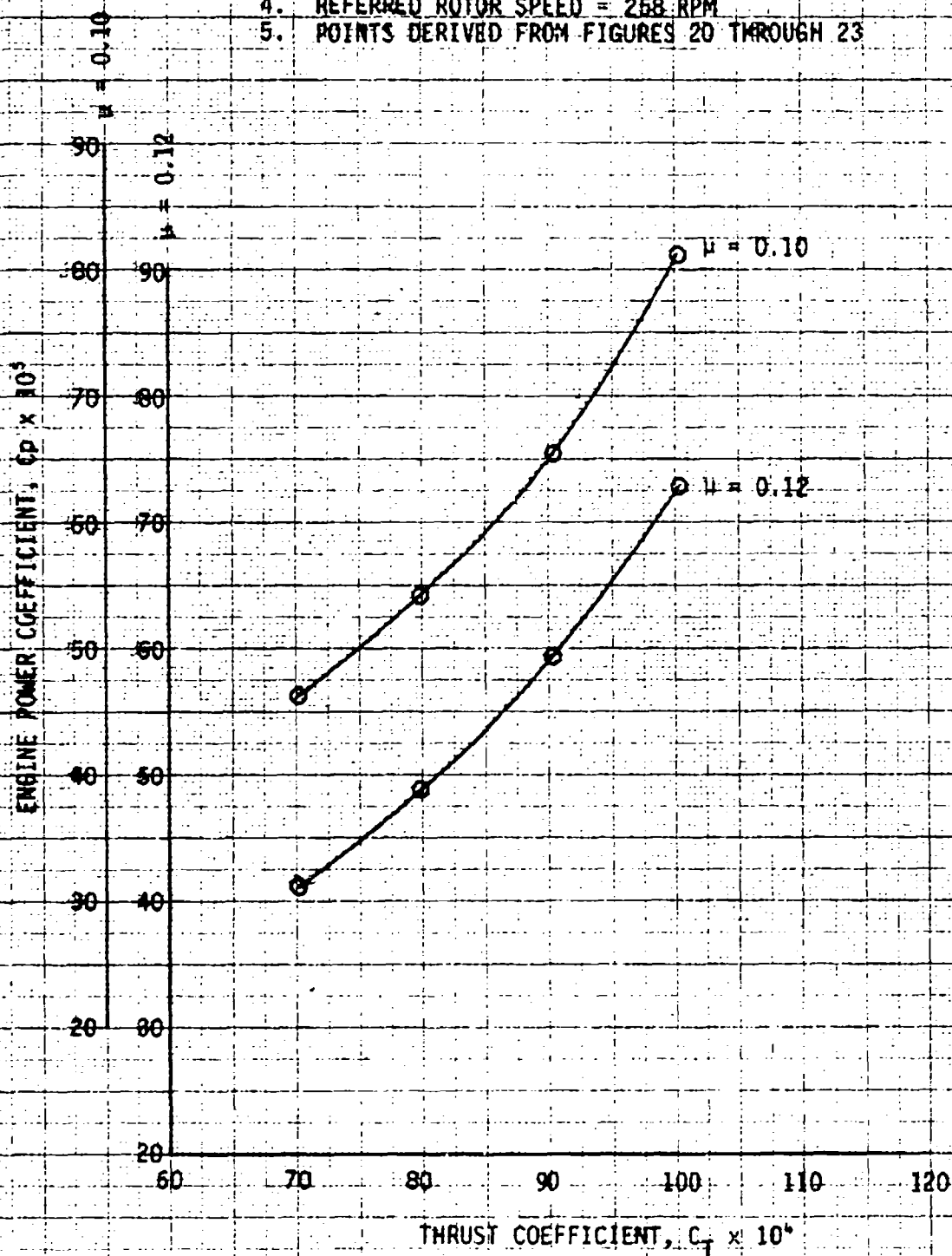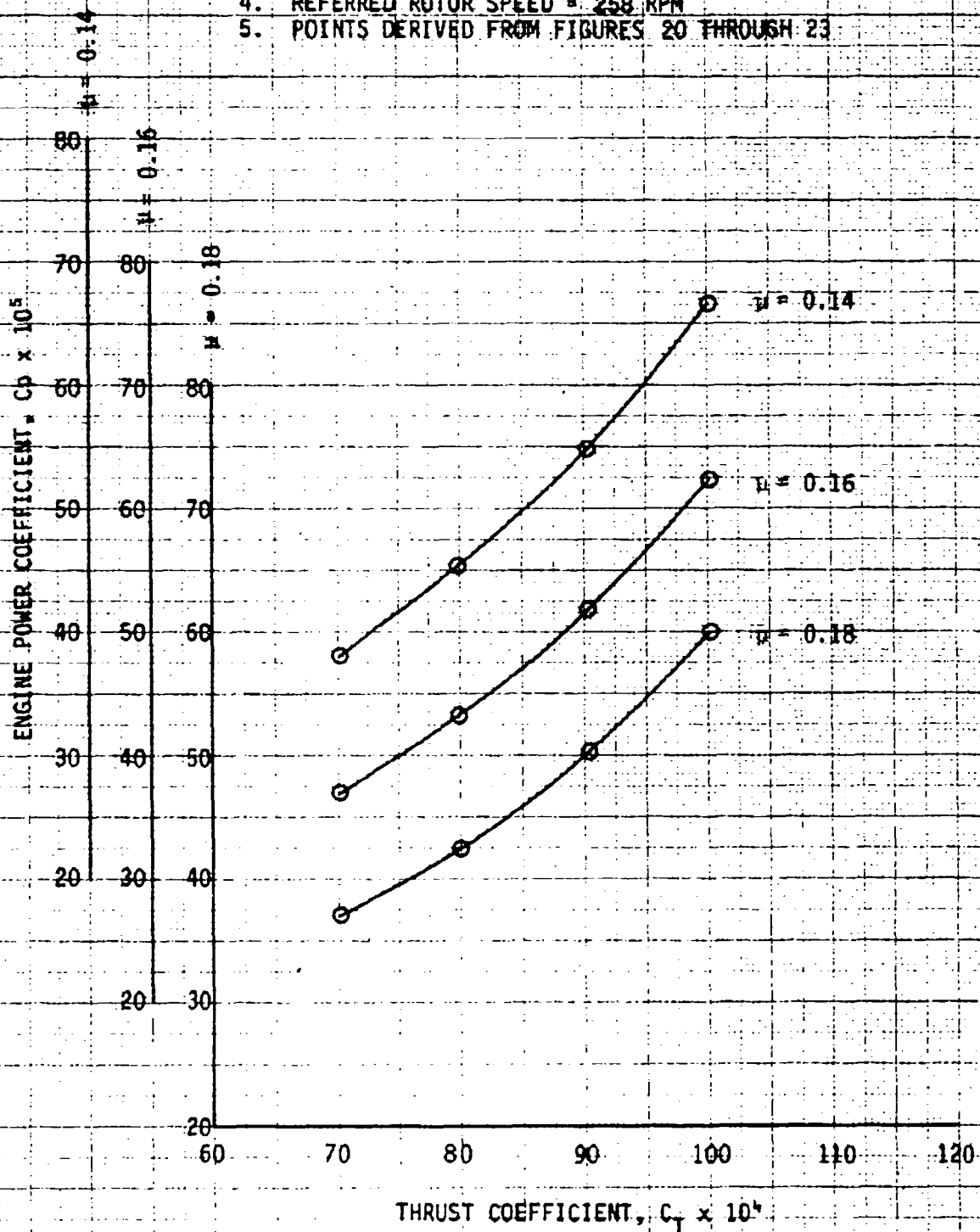   5. POINTS DERIVED FROM FIGURES 20 THROUGH 23
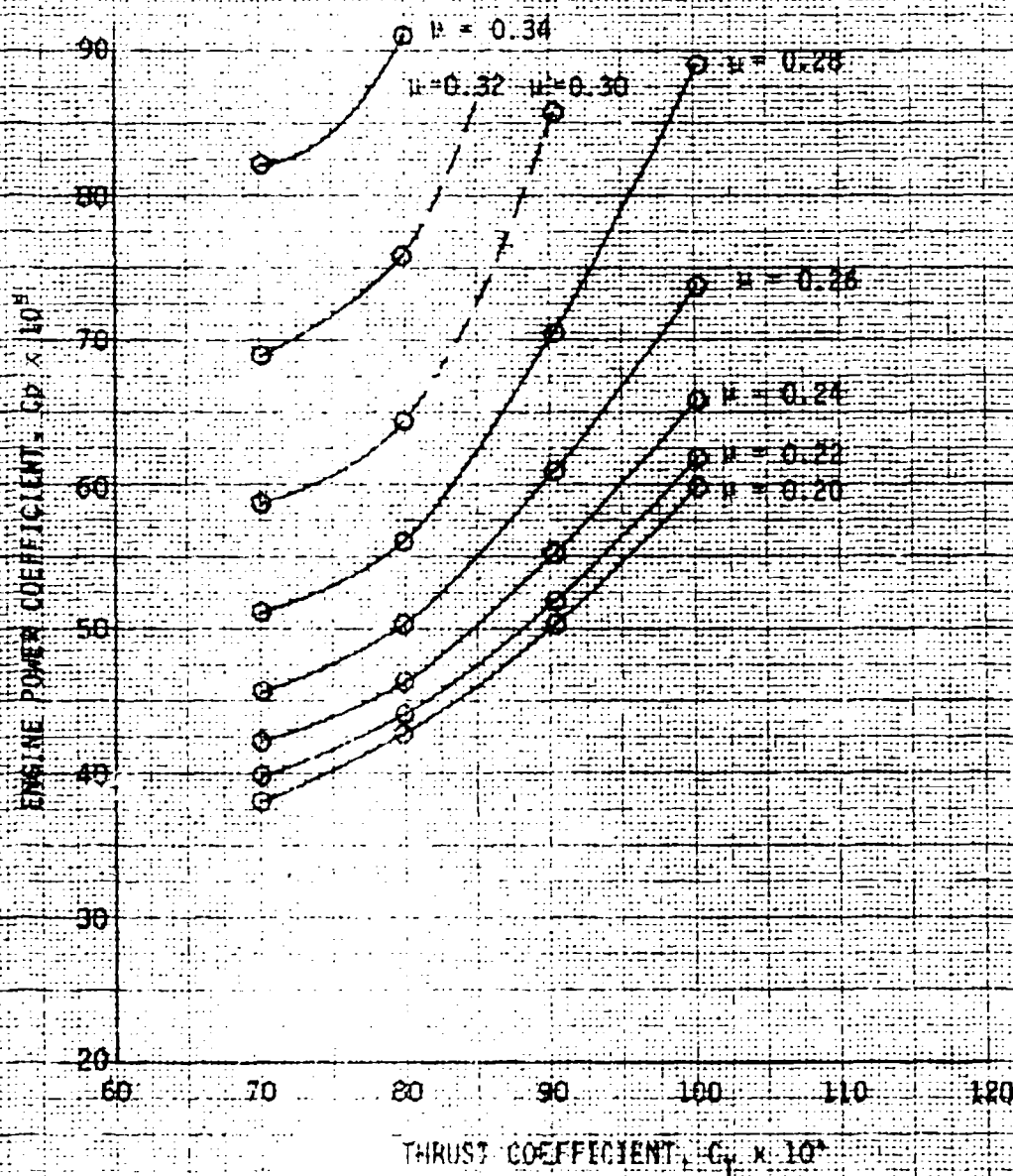
FIGURE 20
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T ×10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
16,080	349.9	0.2R	5920	6.5	257.8	70.08	MODIFIED ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM
FIGURES 33 AND 34

FAIRING DERIVED FROM
FIGURES 17 THROUGH 19

BASELINE DERIVED
FROM A&FC TEST
REPORT 77-17

60
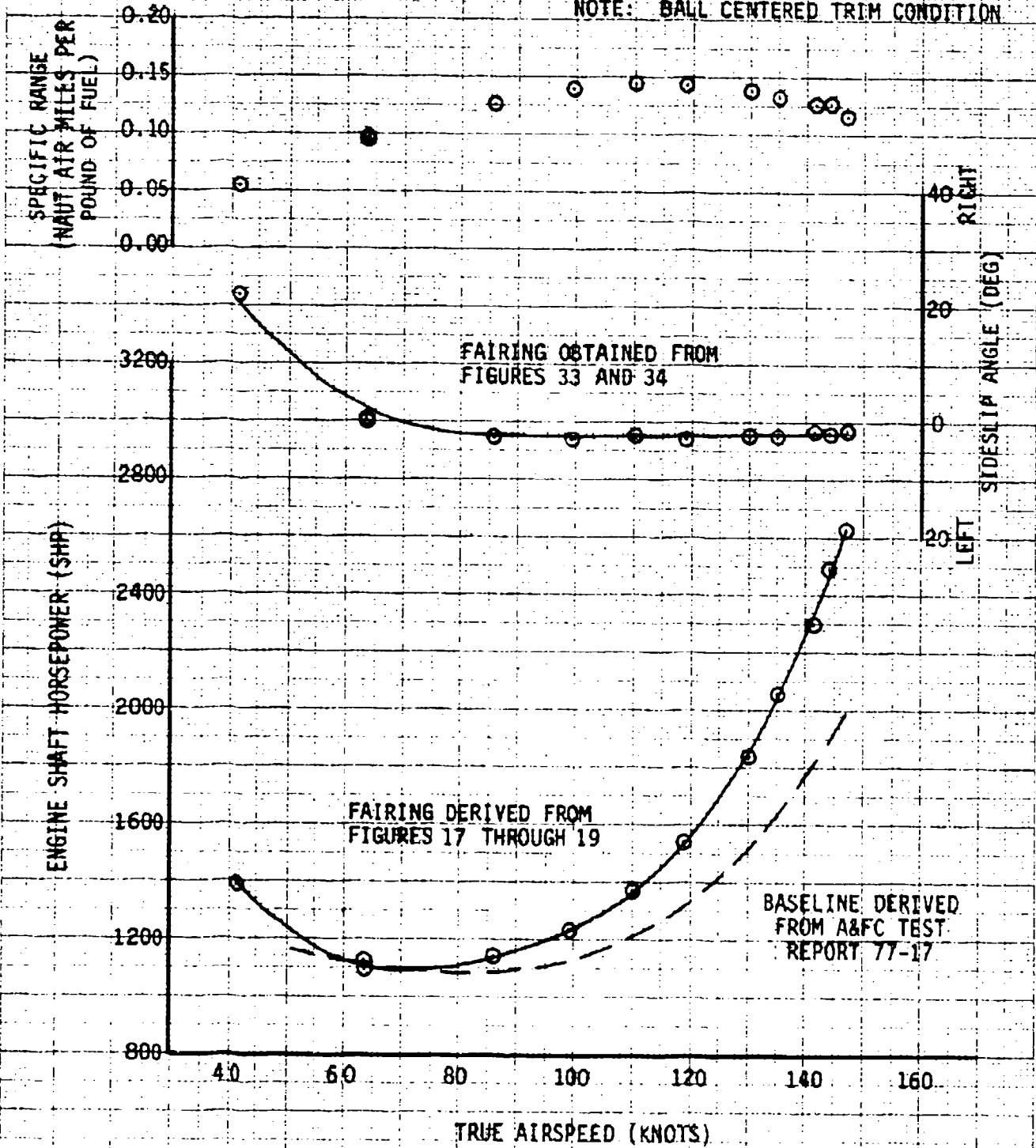
FIGURE 21
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIGURATION
16,080	350.0	0.1R	9640	1.5	258.1	79.86	MODIFIED ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM
FIGURES 33 AND 34

FAIRING DERIVED FROM
FIGURES 17 THROUGH 19

BASELINE DERIVED
FROM A&FC TEST
REPORT 77-17

TRUE AIRSPEED (KNOTS)

61
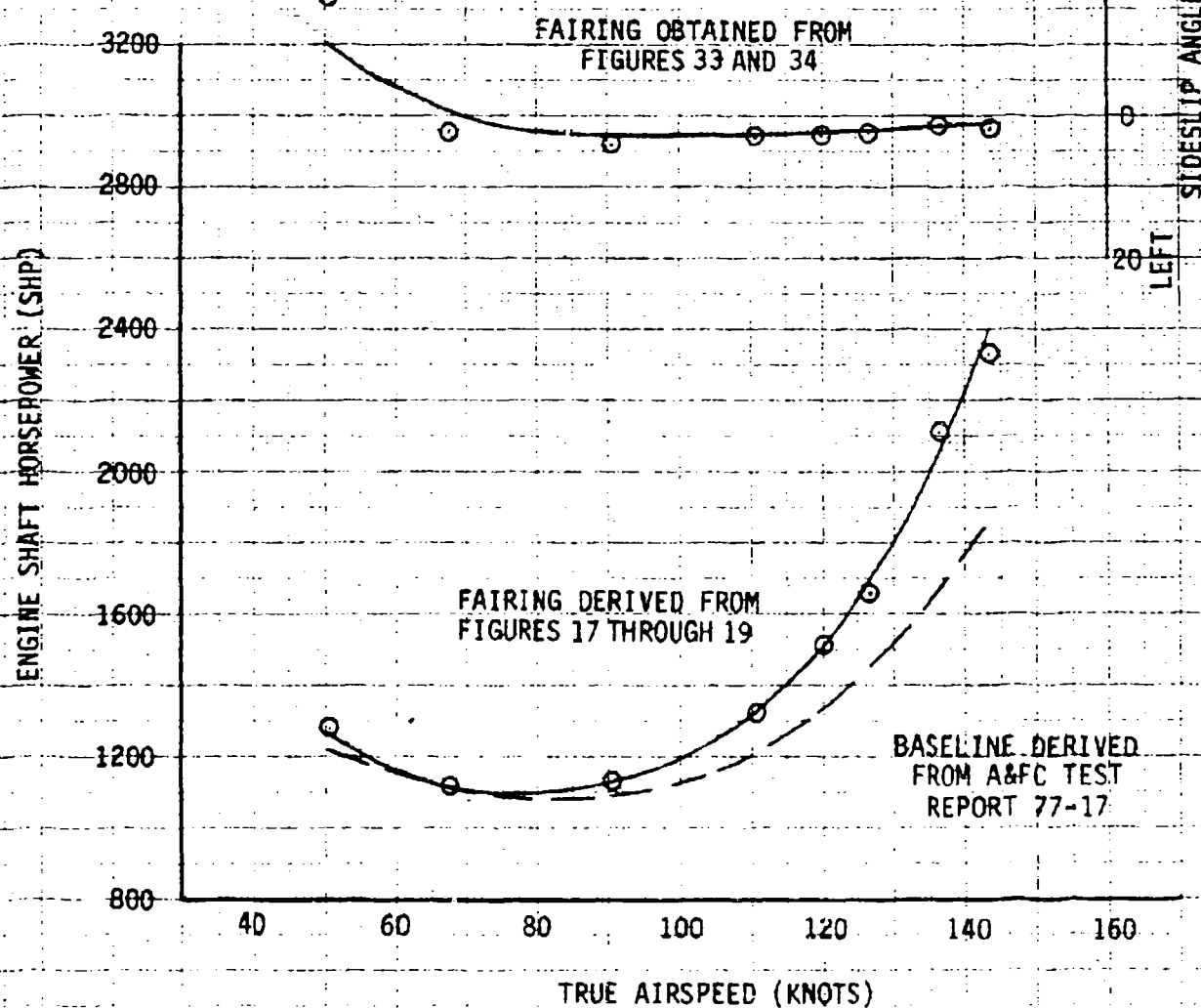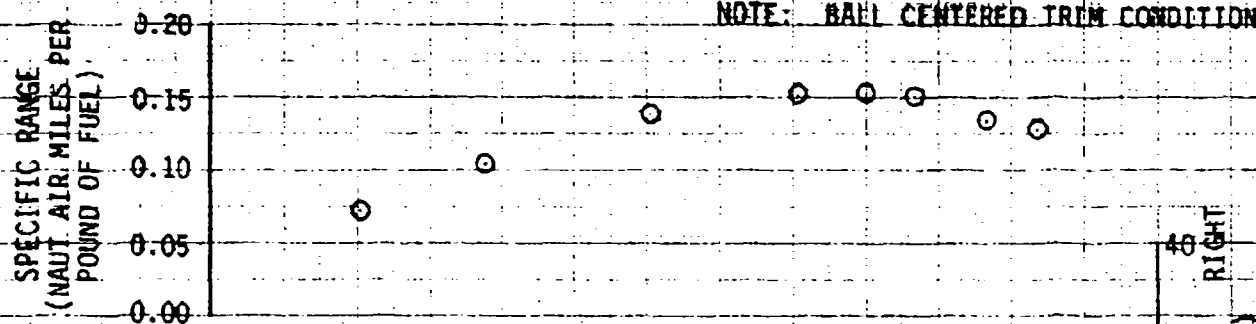
FIGURE 22
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
24,540	343.4	0.1R	820	11.5	257.6	90.33	MODIFIED ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM FIGURES 33 AND 34

FAIRING DERIVED FROM FIGURES 17 THROUGH 19 CORRECTED TO FS 343.4 (1.1 FT² ΔF_e)

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

62
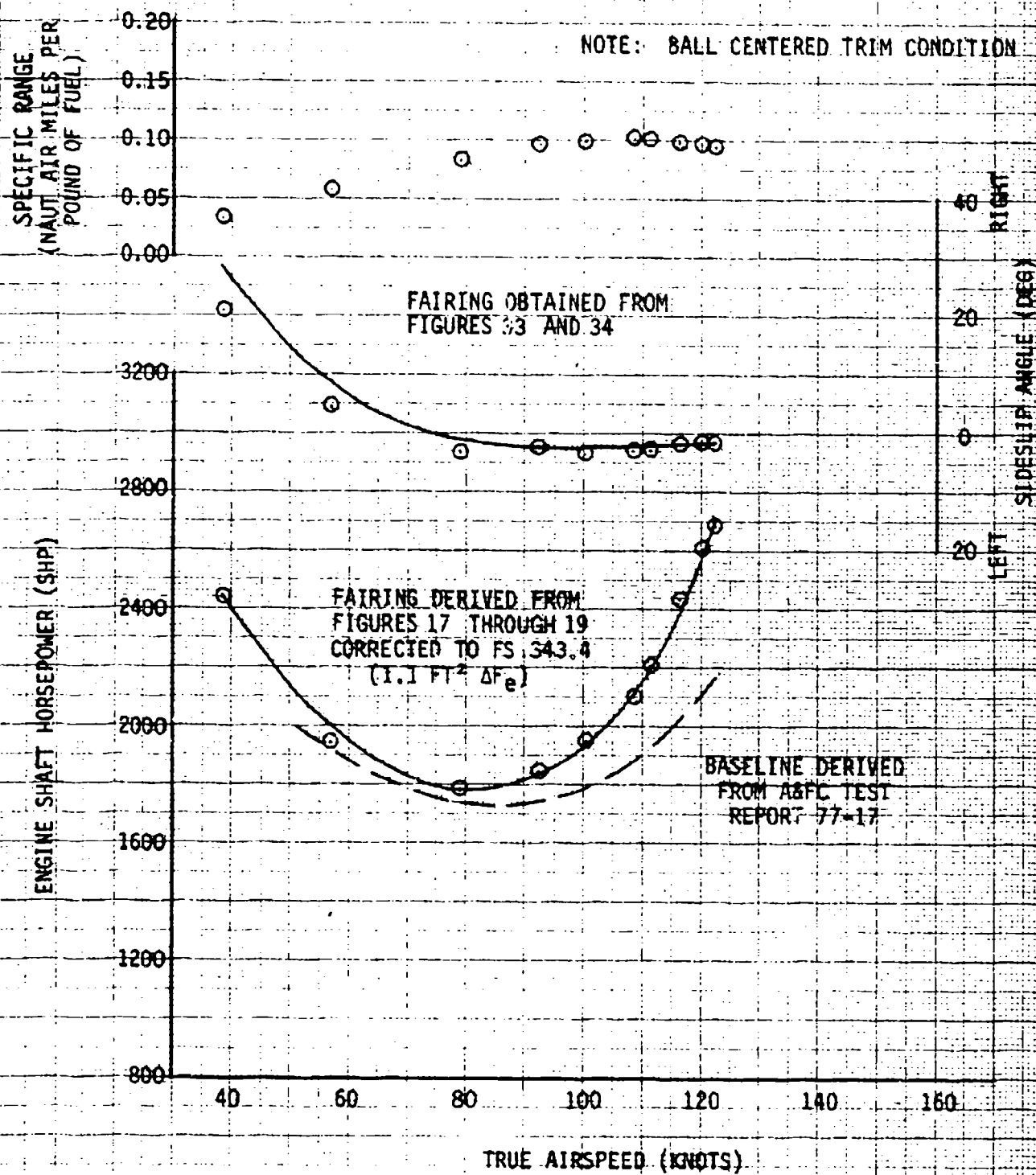
FIGURE 23
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
22,460	350.3	0.2R	6420	4.0	258.0	100.16	MODIFIED ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM FIGURES 33 AND 34

FAIRING DERIVED FROM FIGURES 17 THROUGH 19

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

Axis labels: SPECIFIC RANGE (NAUT. AIR MILES PER POUND OF FUEL); ENGINE SHAFT HORSEPOWER (SHP); SIDESLIP ANGLE (DEG) RIGHT/LEFT; TRUE AIRSPEED (KNOTS)
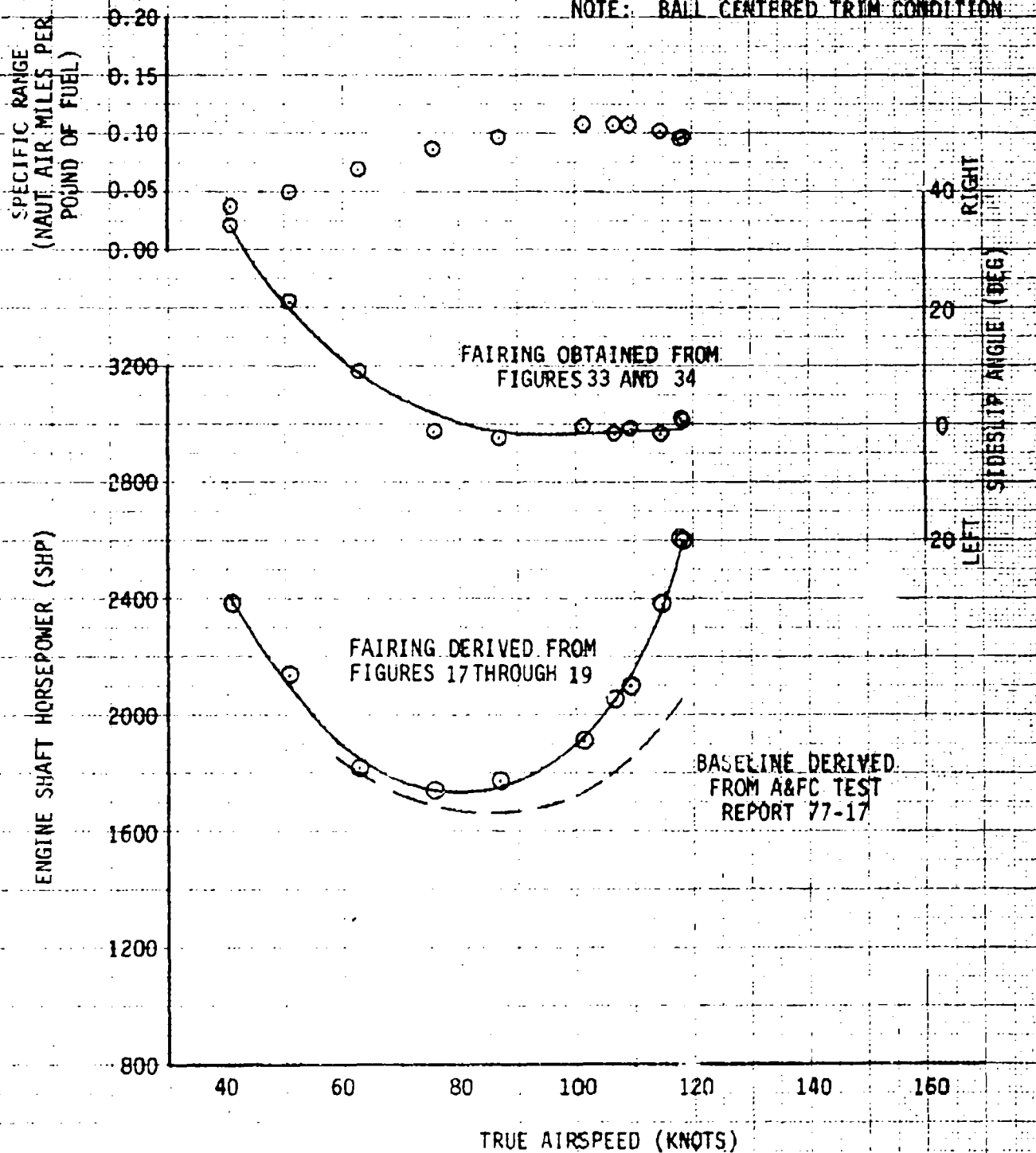
63

FIGURE 24
DRAG CHANGE SUMMARY FOR ORIGINAL ESSS ONLY AND WITH TWO TANKS
UH-6LA USA S/N 77-22714

CONFIGURATION	LONGITUDINAL CG LOCATION (FS)	THRUST COEFFICIENT $\times 10^4$
ORIGINAL ESSS WITH NO STORES	346.9	70.20
	347.0	80.32
ORIGINAL ESSS WITH TWO TANKS	346.7	70.14
	347.0	80.24
	347.2	90.18

NOTES: 1. BALL CENTERED TRIM CONDITION
2. FAIRINGS DERIVED FROM FIGURES 25 THROUGH 27 AND 31 AND 32
3. BASELINE ($\Delta F_e = 0$) IS THE A&FC DATA FOR THE NORMAL UTILITY CONFIGURATION NORMALIZED TO THE TEST AIRCRAFT (INHERENT SIDESLIP, CONFIGURATION DIFFERENCES, LONGITUDINAL CG AND UNEXPLAINED ΔF_e DIFFERENCE, FIGURE 2)

64
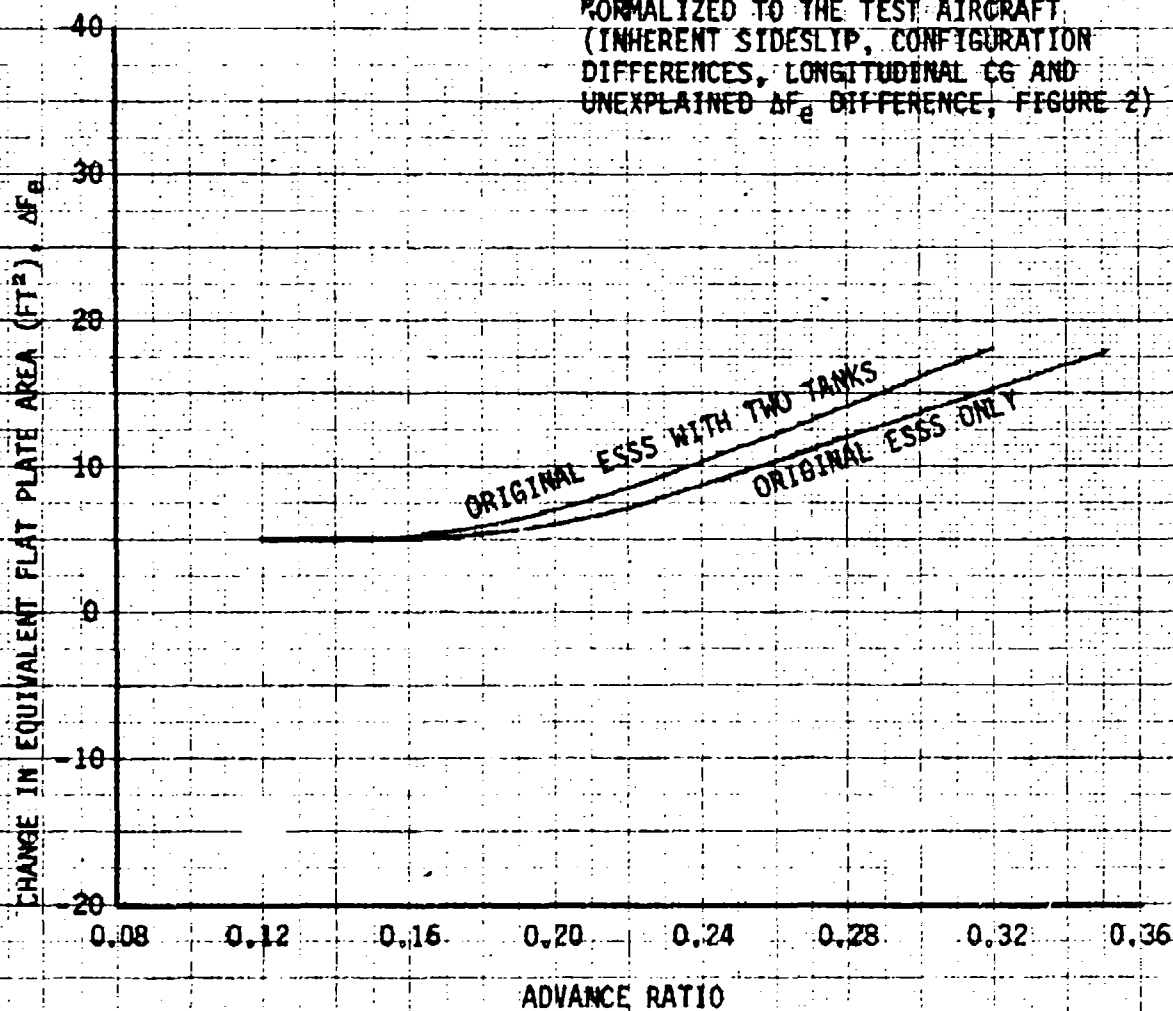
FIGURE 25
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH TWO 230 GAL TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 347.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 28 THROUGH 30

65
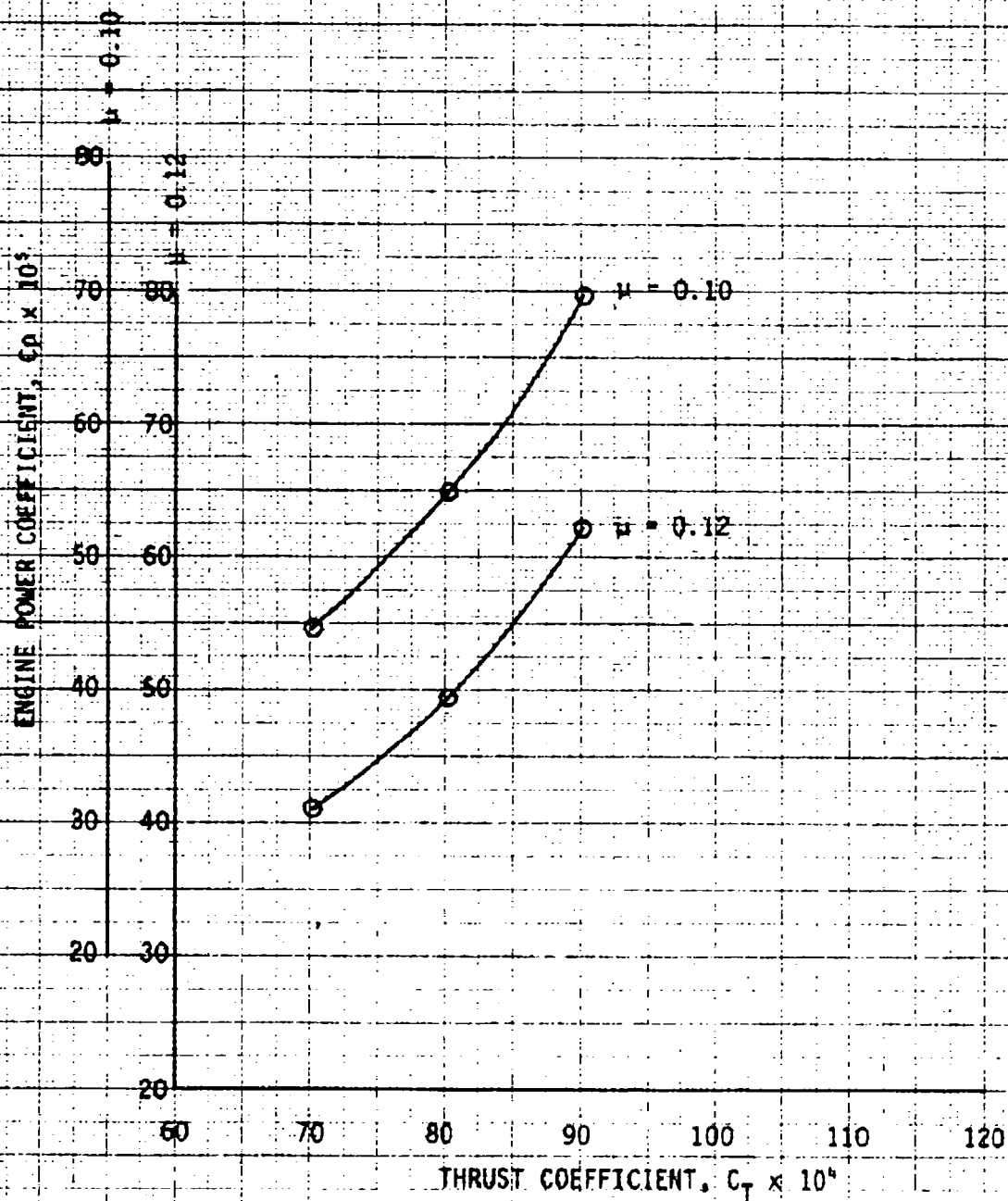
FIGURE 26
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH TWO 230 GAL TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 347.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 28 THROUGH 30

66

FIGURE 27
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

CONFIGURATION: ORIGINAL ESSS WITH TWO 230 GAL TANKS

NOTES: 1. BALL-CENTERED TRIM CONDITION
2. LONGITUDINAL CG (FS 347.0)
3. MID LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
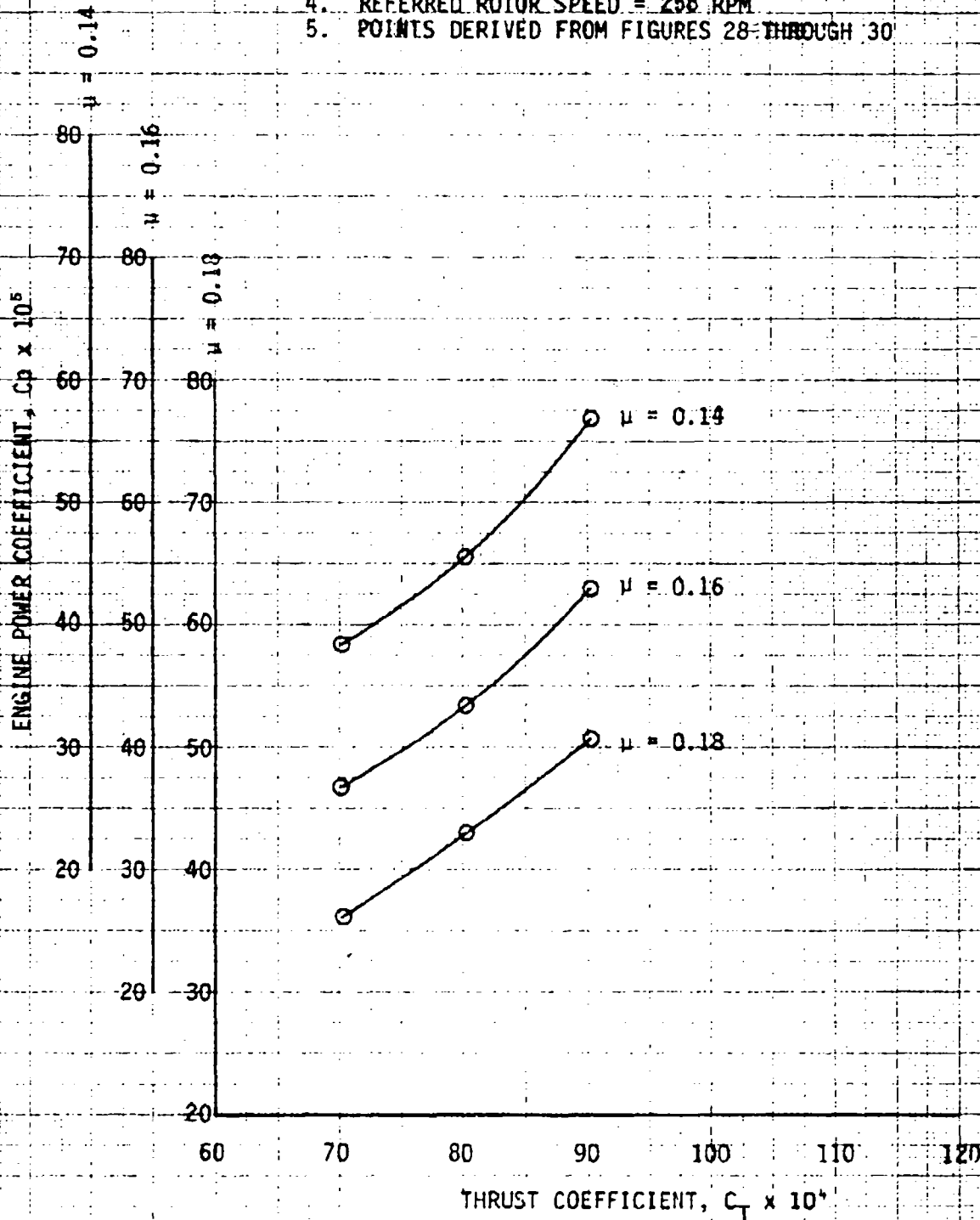5. POINTS DERIVED FROM FIGURES 28 THROUGH 30

67

FIGURE 28
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
17,900	346.7	0.2R	2660	9.0	257.7	70.14	ORIGINAL ESSS WITH TWO TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM
FIGURES 33 AND 34

FAIRING DERIVED FROM
FIGURES 25 THROUGH 27

BASELINE DERIVED
FROM A&FC TEST
REPORT 77-17

68

FIGURE 29
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

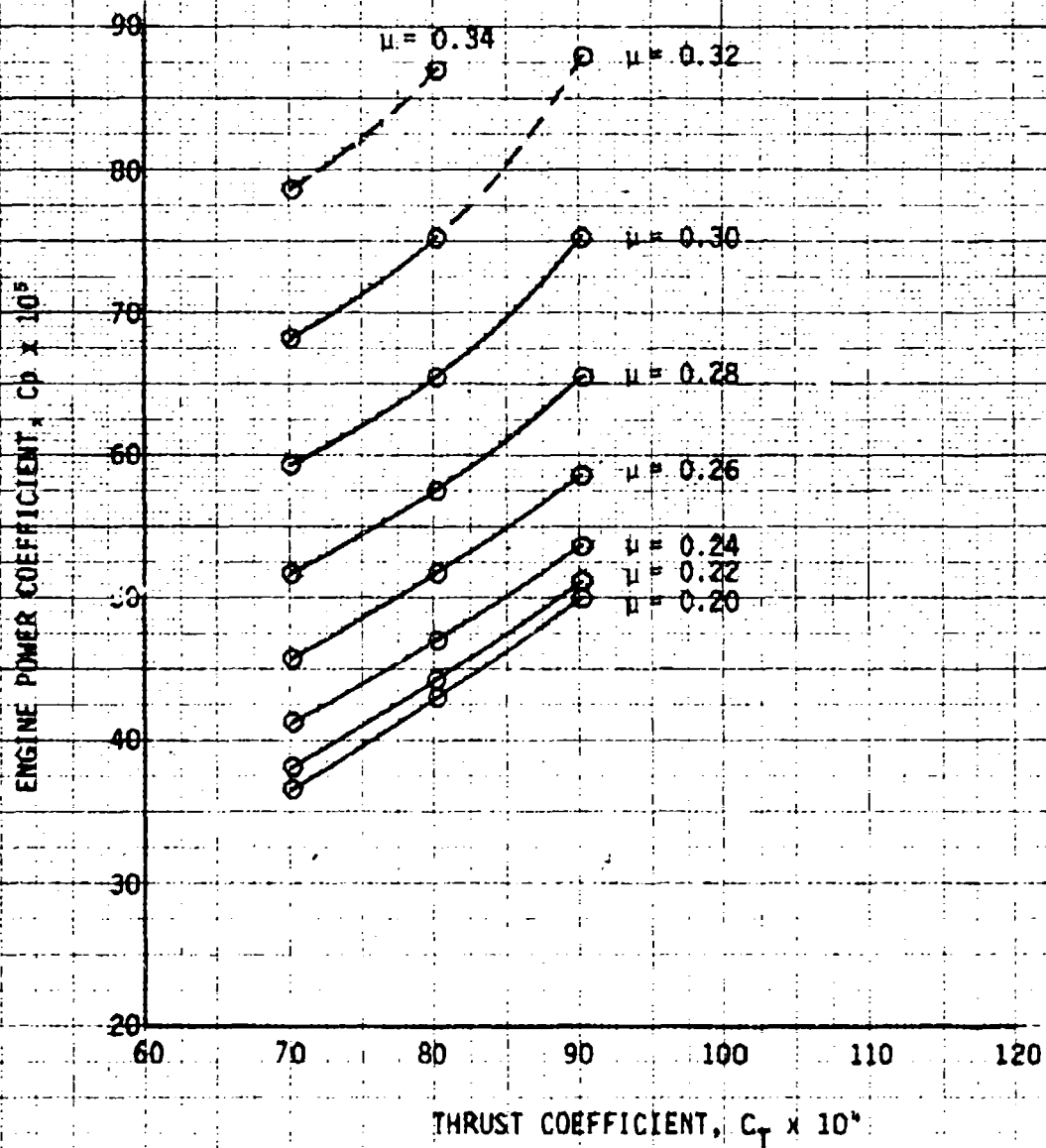| AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
19,920	347.0	0.2R	4360	15.0	258.0	80.24	ORIGINAL ESSS WITH TWO TANKS

NOTE: BALL CENTERED TRIM CONDITION

FIGURE 30
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
21,880	347.2	0.1R	5120	14.5	258.2	90.18	ORIGINAL ESSS WITH TWO TANKS

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM FIGURES 33 AND 34

FAIRING DERIVED FROM FIGURES 25 THROUGH 27

BASELINE DERIVED FROM A&FC TEST REPORT 77-17
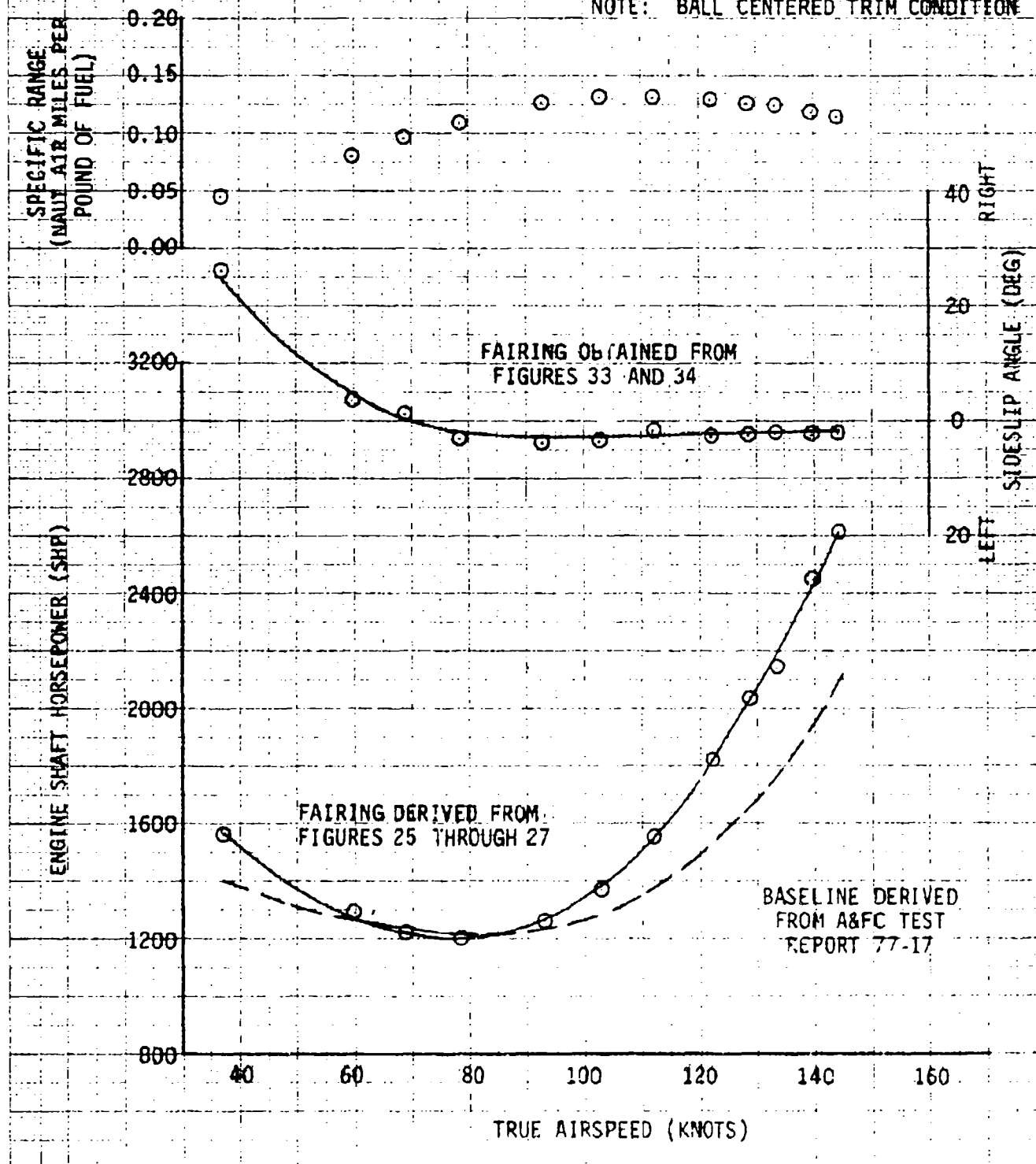
TRUE AIRSPEED (KNOTS)

FIGURE 31
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T $\times 10^4$	AIRCRAFT CONFIGURATION
16,080	346.9	0.3R	6740	12.0	258.3	70.20	ORIGINAL ESSS WITH NO STORES

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM
FIGURES 33 AND 34

FAIRING DERIVED FROM A&FC
FINAL REPORT 77-17 AND
FIGURE 24

BASELINE DERIVED FROM
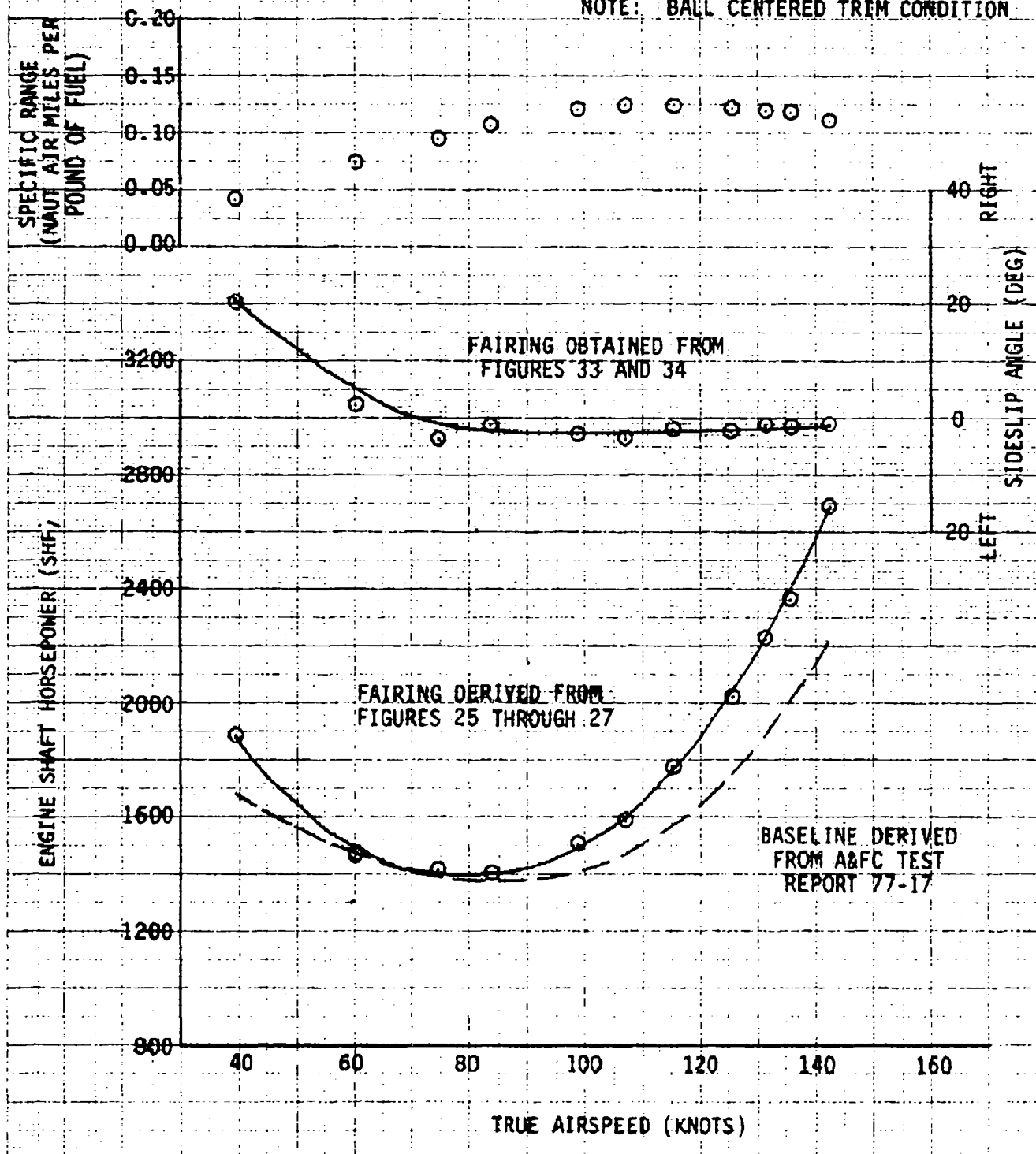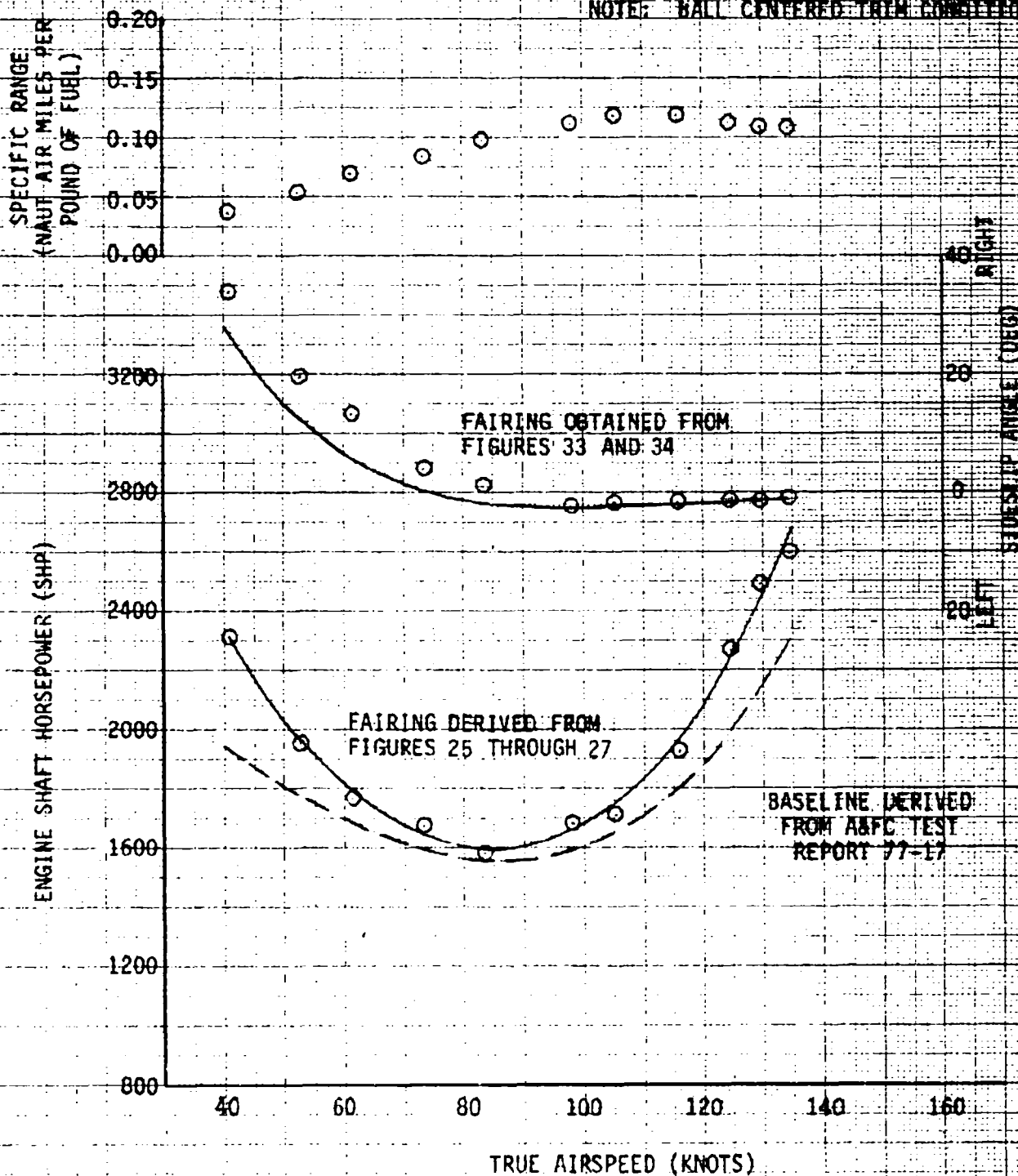A&FC TEST REPORT 77-17

71
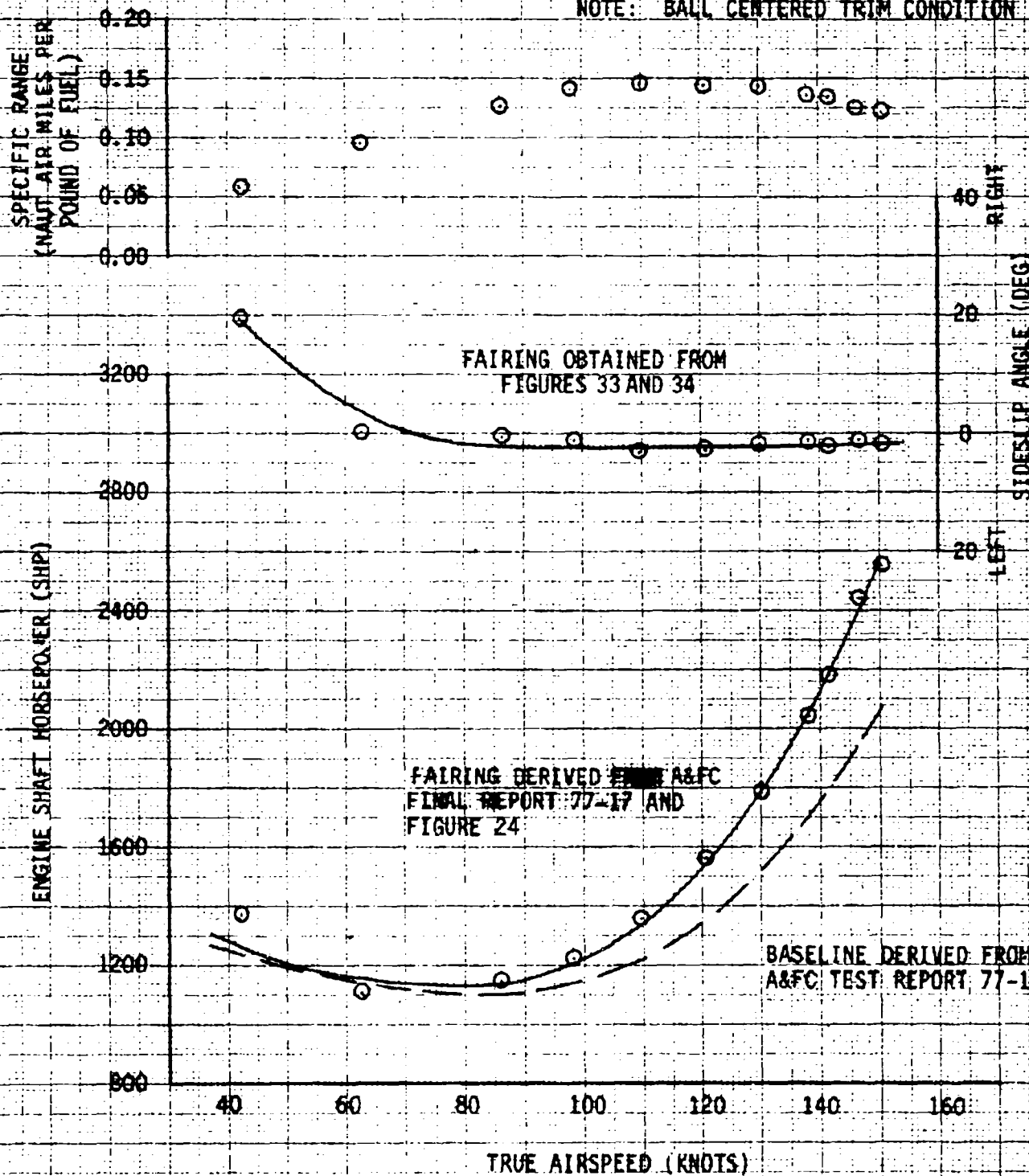
FIGURE 32
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG REFERRED ROTOR SPEED (RPM)	AVG C_T x10⁴	AIRCRAFT CONFIGURATION
	LONG (FS)	LAT (BL)					
17,960	347.0	0.2 R	7300	10.0	258.3	80.32	ORIGINAL ESSS WITH NO STORES

NOTE: BALL CENTERED TRIM CONDITION

FAIRING OBTAINED FROM FIGURES   AND

FAIRING DERIVED FROM A&FC FINAL REPORT 77-17 AND FIGURE 24

BASELINE DERIVED FROM A&FC TEST REPORT 77-17

TRUE AIRSPEED (KNOTS)

72

FIGURE 33
INHERENT SIDESLIP ANGLE
UH-60A USA S/N 77-22714

NOTES: 1. FAIRINGS DERIVED FROM FIGURES 3 THROUGH 32 AND ARE REPRESENTATIVE OF ALL AIRCRAFT CONFIGURATIONS AND LONGITUDINAL CG LOCATIONS TESTED
2. MID LATERAL CG

73
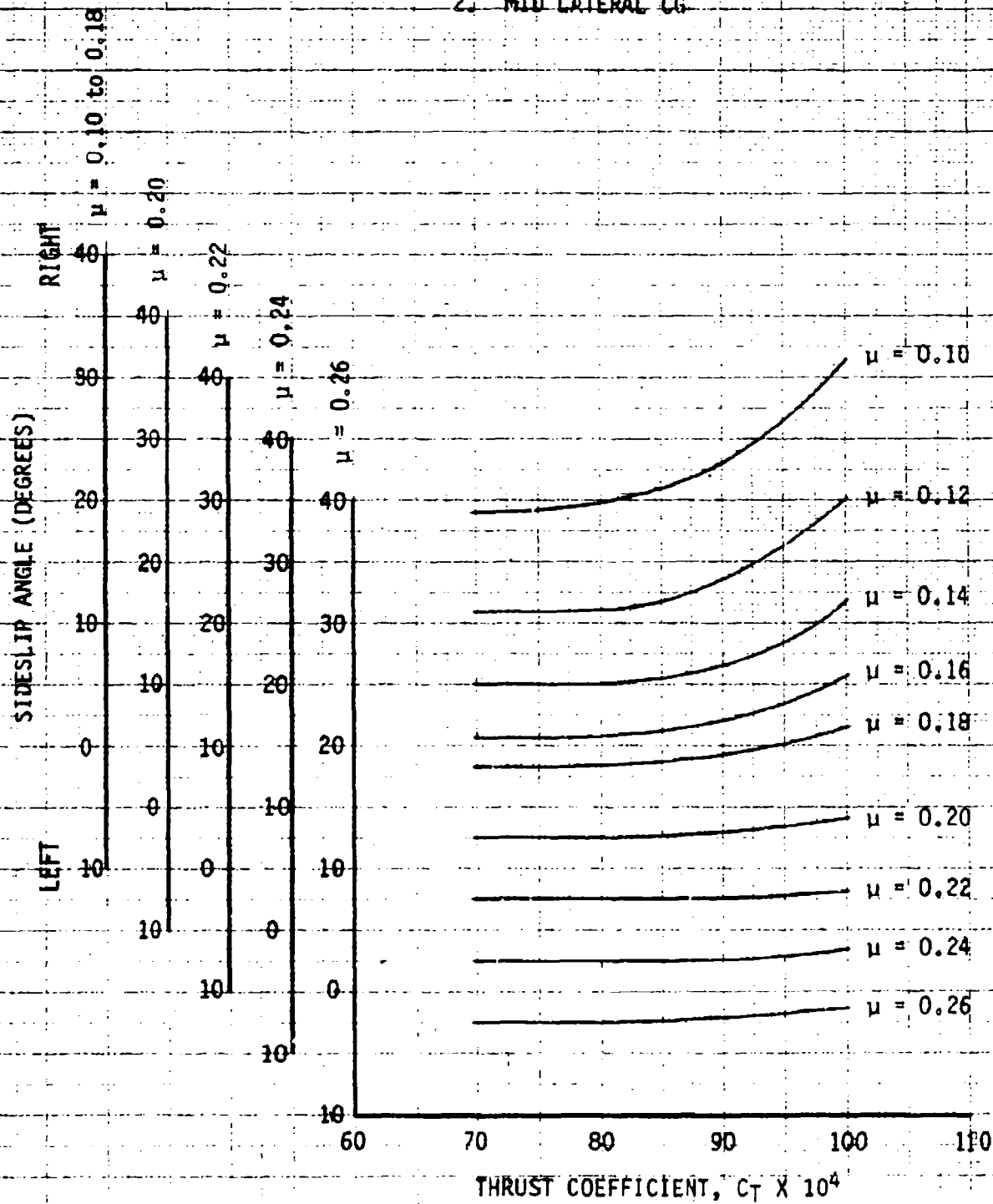
FIGURE 34
INHERENT SIDESLIP ANGLE
UH-60A USA S/N 77-22714

NOTES: 1. FAIRINGS DERIVED FROM FIGURES 3 THROUGH 32 AND ARE REPRESENTATIVE OF ALL AIRCRAFT CONFIGURATIONS AND LONGITUDINAL CG LOCATIONS TESTED
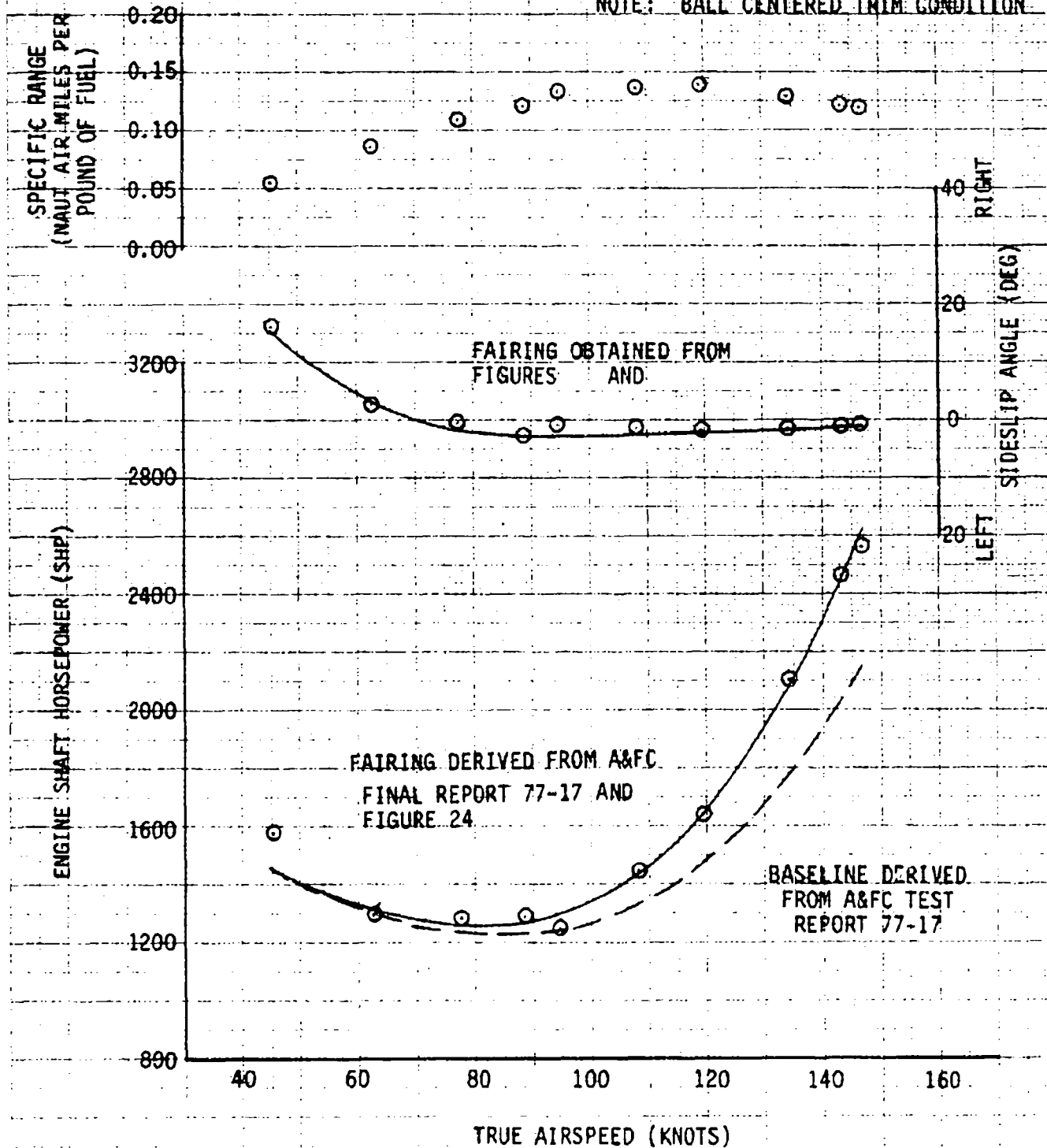2. MID LATERAL CG

FIGURE 38
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
18,000	346.8	0.2 RT	6080	8.5	255	FIXED PROVISIONS

NOTE: BALL CENTERED TRIM CONDITION.

CALIBRATED AIRSPEED (KNOTS)

FIGURE 16
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
	LONG (FS)	LAT (BL)				
17,960	347.0	0.2 RT	7300	10.0	258	ORIGINAL ESSS WITH NO STORES

NOTE: BALL CENTERED TRIM CONDITION

INSTRUMENTATION INOPERATIVE

CALIBRATED AIRSPEED (KNOTS)

16

FIGURE 37
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

AVG GROSS WEIGHT (LB)	AVG CG LOCATION		AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
	LONG (FS)	LAT (BL)				
19,920	347.0	0.2 RT	4360	15.0	258	ORIGINAL ESSS WITH TWO TANKS

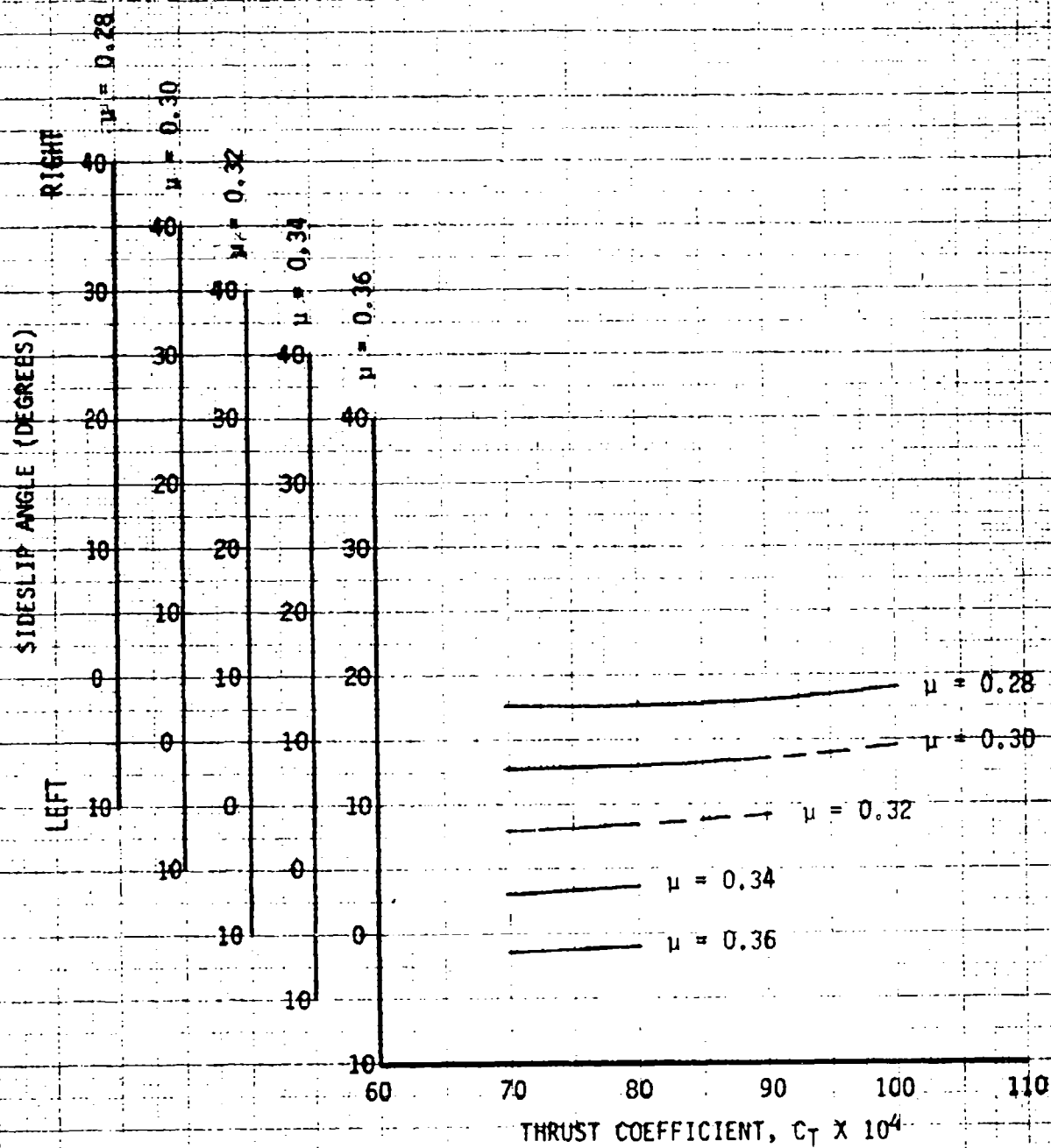NOTE: BALL CENTERED TRIM CONDITION
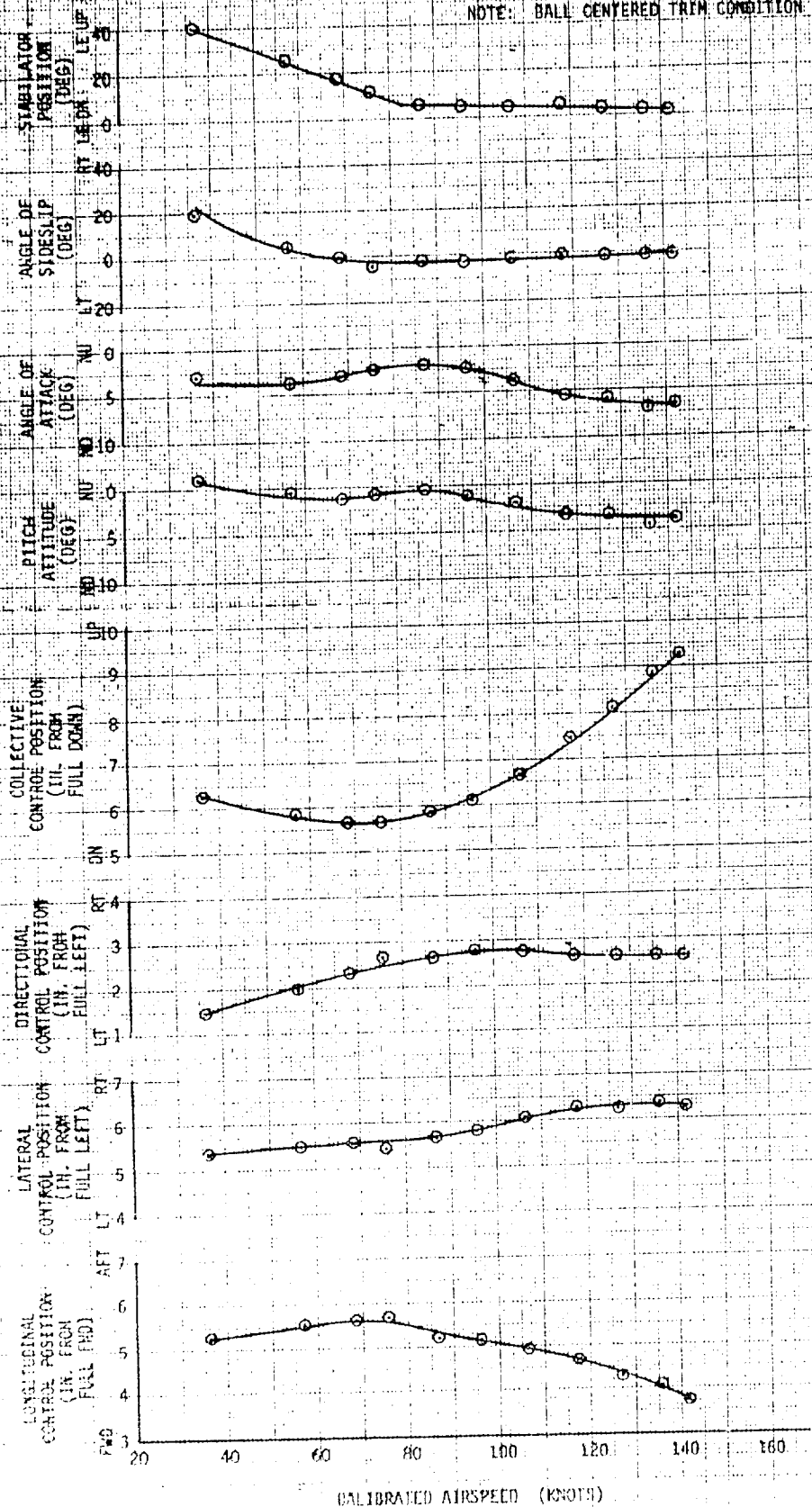
CALIBRATED AIRSPEED (KNOTS)

FIGURE 38
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
O	16,040	350.2	0.2 RT	10,380	7.5	254	ORIGINAL ESSS WITH FOUR TANKS
△	16,080	350.0	0.1 RT	9640	1.5	252	MODIFIED ESSS WITH FOUR TANKS

NOTE: BALL CENTERED TRIM CONDITION
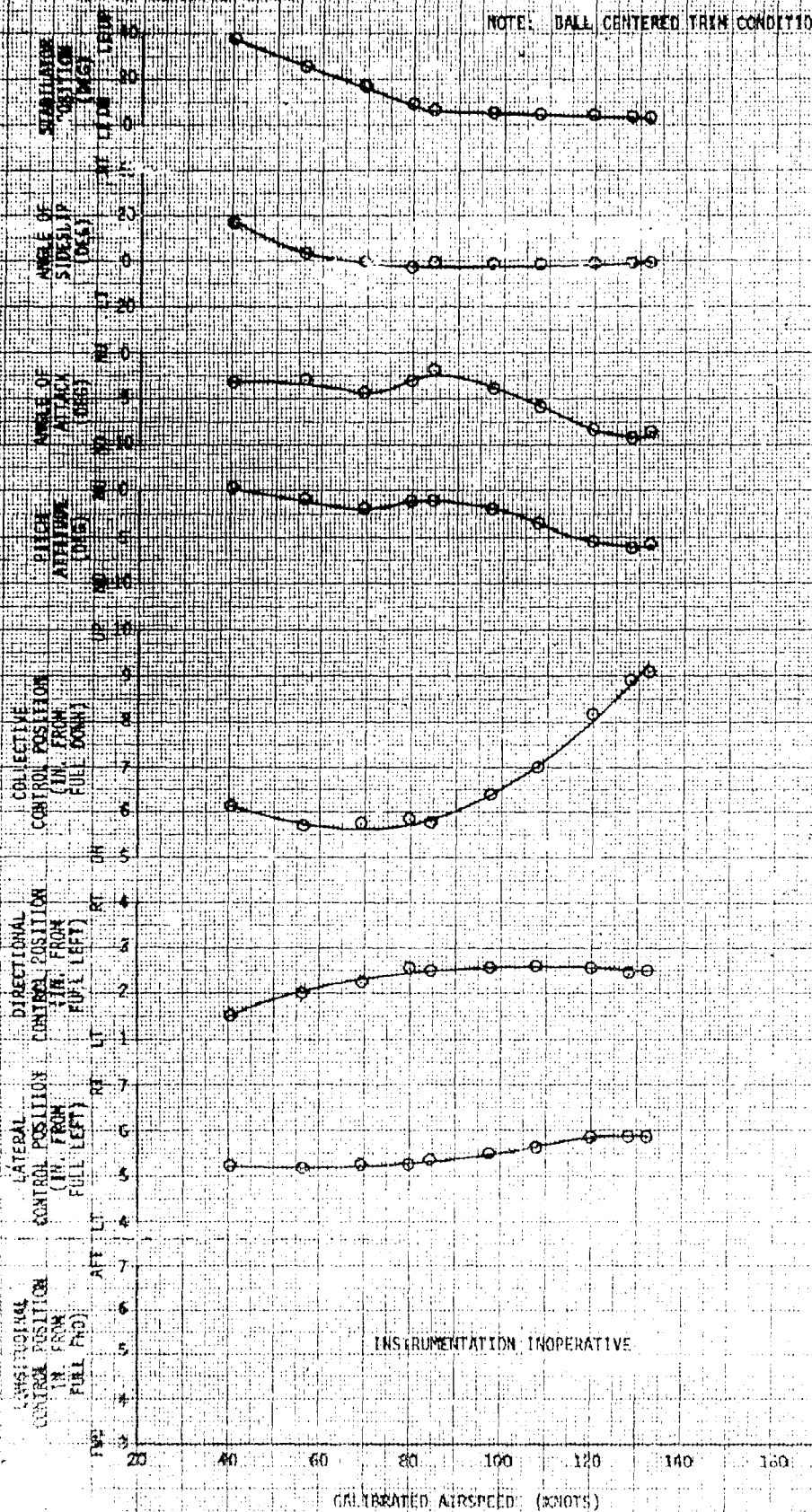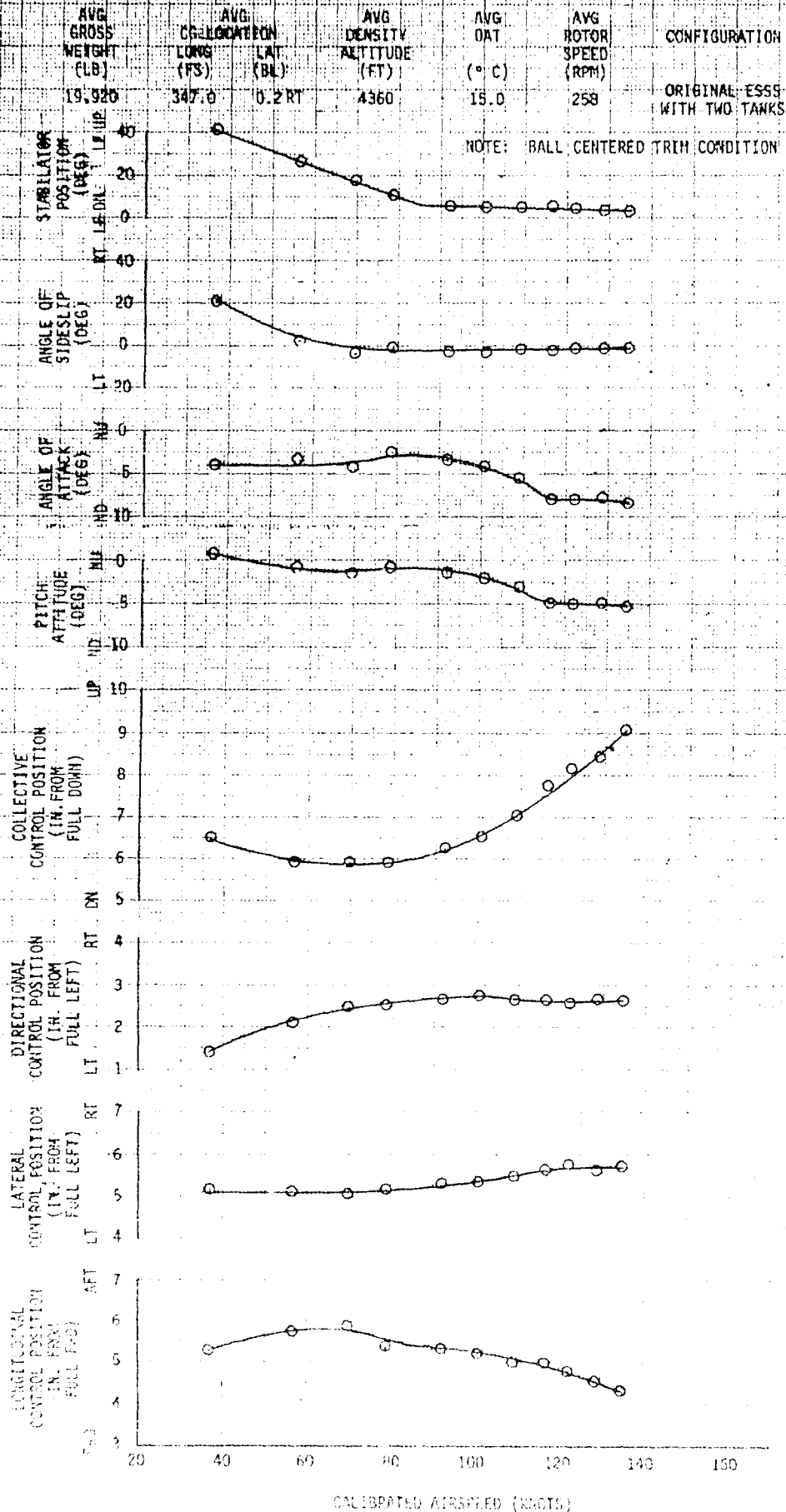
CALIBRATED AIRSPEED (KNOTS)

FIGURE 89
CONTROL POSITIONS IN LEVEL FLIGHT
UH-60A USA S/N 77-22714

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	CONFIGURATION
O	24,580	343.3 (FWD)	0.2 RT	1380	16.5	258	ORIGINAL ESSS WITH FOUR TANKS
△	17,960	343.0 (FWD)	0.2 RT	10,740	7.5	255	

NOTE: BALL CENTERED TRIM CONDITION

CALIBRATED AIRSPEED (KNOTS)

79
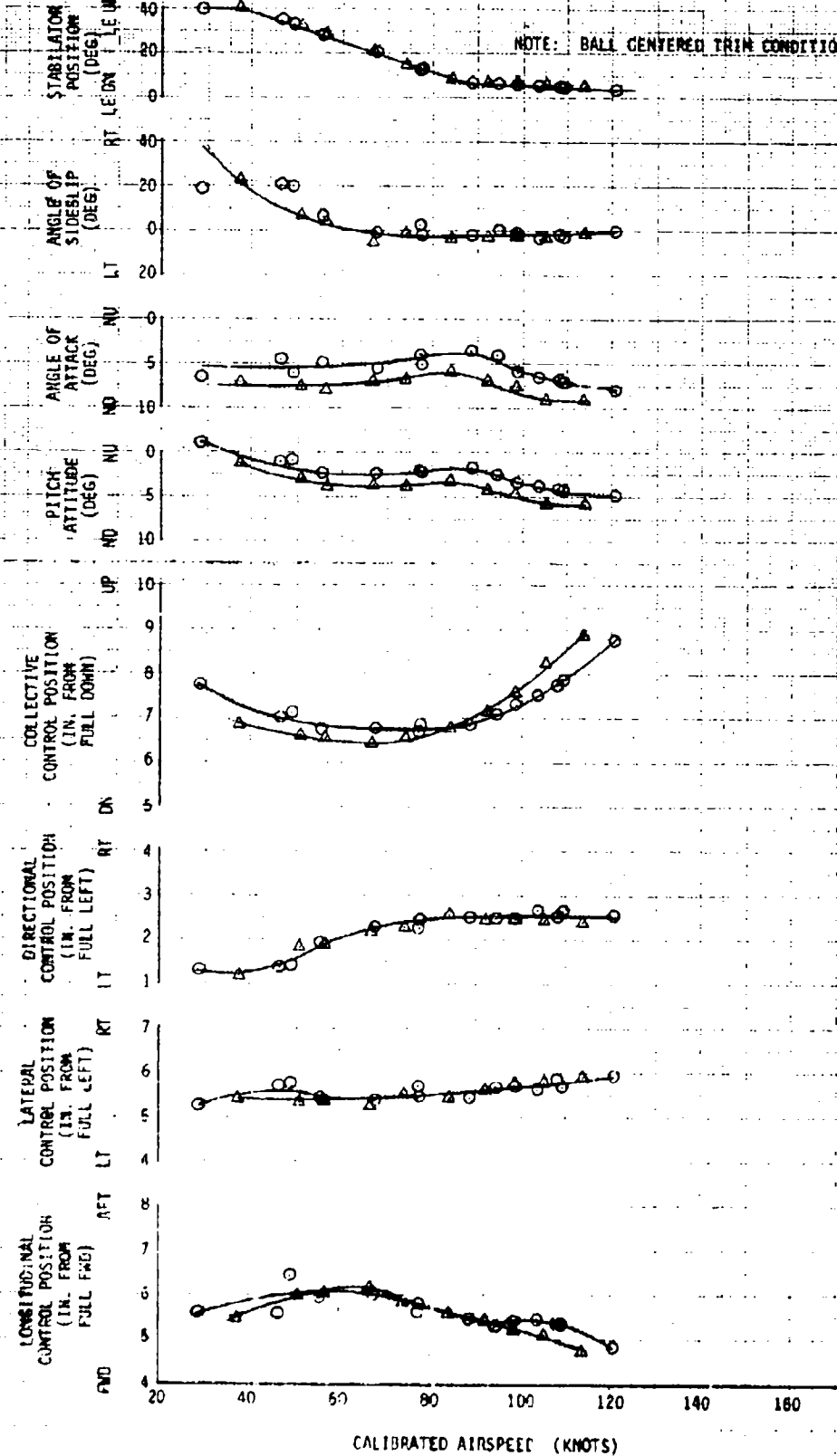
APPENDIX F. GLOSSARY

A&FC	Airworthiness and Flight Characteristics
app	appendix
AVRADCOM	US Army Aviation Research and Development Command
BL	buttline
CG	center of gravity
C_T	thrust coefficient
ESSS	External Stores Support System
fig.	figure
FS	fuselage station
ft	feet
GE	General Electric
KT	knot
KTAS	knots true airspeed
lb	pound
PAE	Preliminary Airworthiness Evaluation
RPM	revolutions per minute
SA	Sikorsky Aircraft Division of United Technologies
SHP	shaft horsepower
ΔFe	change in equivalent flat plate area

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US Army Combined Arms Center (ATZLCA-DM)	1
US Army Safety Center (IGAR-TA, IGAR-Library)	2

US Army Research and Technology Laboratories
(DAVDL-AS, DAVDL-POM (Library))   2

US Army Research and Technology Laboratories/Applied
Technology Laboratory (DAVDL-ATL-D, DAVDL-Library)   2

US Army Research and Technology Laboratories/Aeromechanics
Laboratory (DAVDL-AL-D)   1

US Army Research and Technology Laboratories/Proplusion
Laboratory (DAVDL-PL-D)   1

Defense Technical Information Center (DDR)   12

US Military Academy (MADN-F)   1

MTMC-TEA (MTT-TRC)   1

ASD/AFXT   1

Project Manager, BLACK HAWK (DRCPM-BH)   5

US Army Material Development and Readiness Command
(DRCDE-SA, DRCQA-ST)   4

US Army Aviation Development Test Activity (STEBG-CT)   2

US Army Troop Support and Aviation Materiel Readiness
Command (DRSTS-WC)   2

US Army Infantry Center (ATSH-TSM-BH)   2

US Army Materiel Systems Analysis Agency (DRXSY-AAM)   2

US Army Operational Test and Evaluation Agency
(CSTE-TM-AV)   2

General Electric (Mr. Koon)   2

Sikorsky Aircraft Division, United Technologies
Corporation (Mr. Richard Connor)   5